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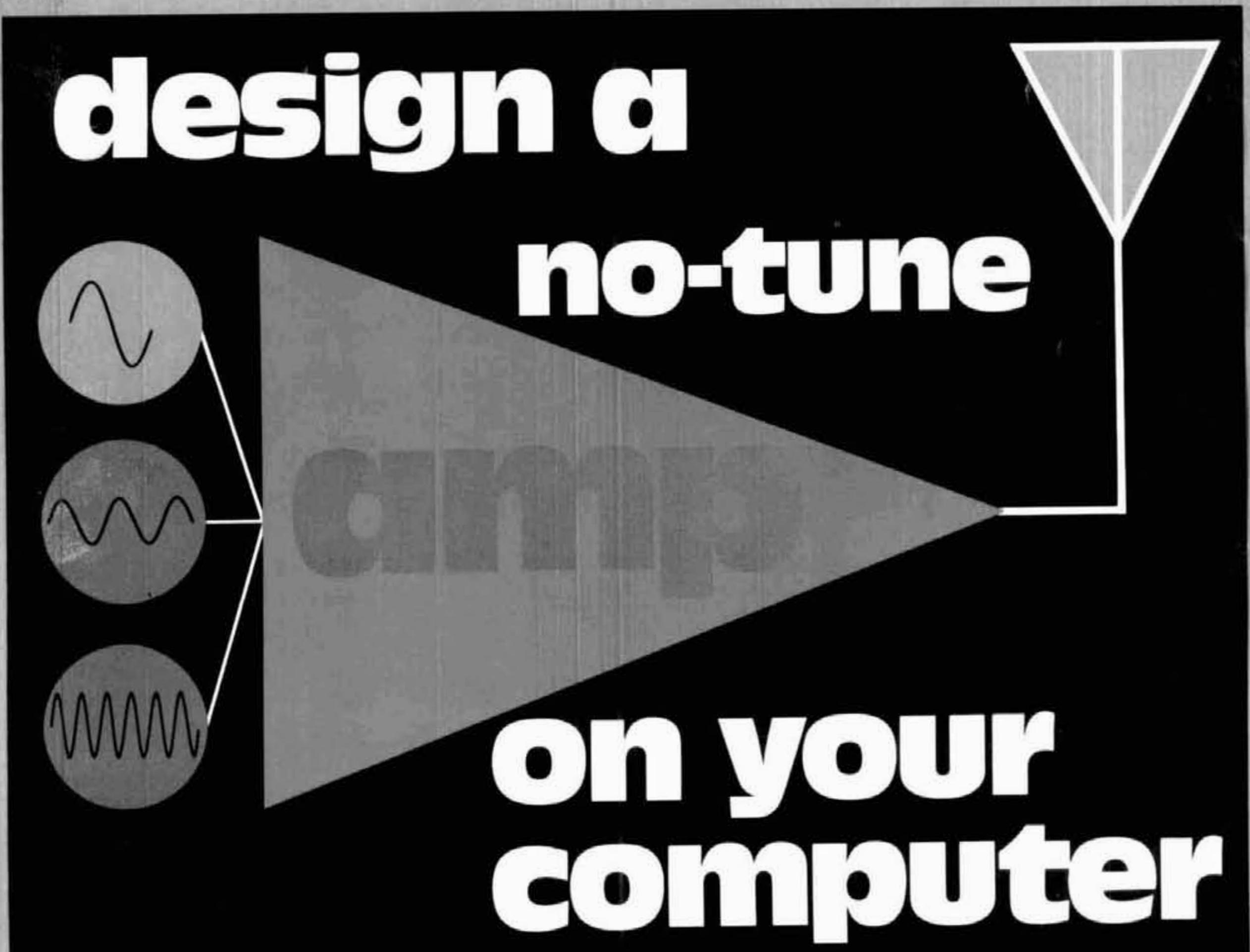
ham radio
magazine



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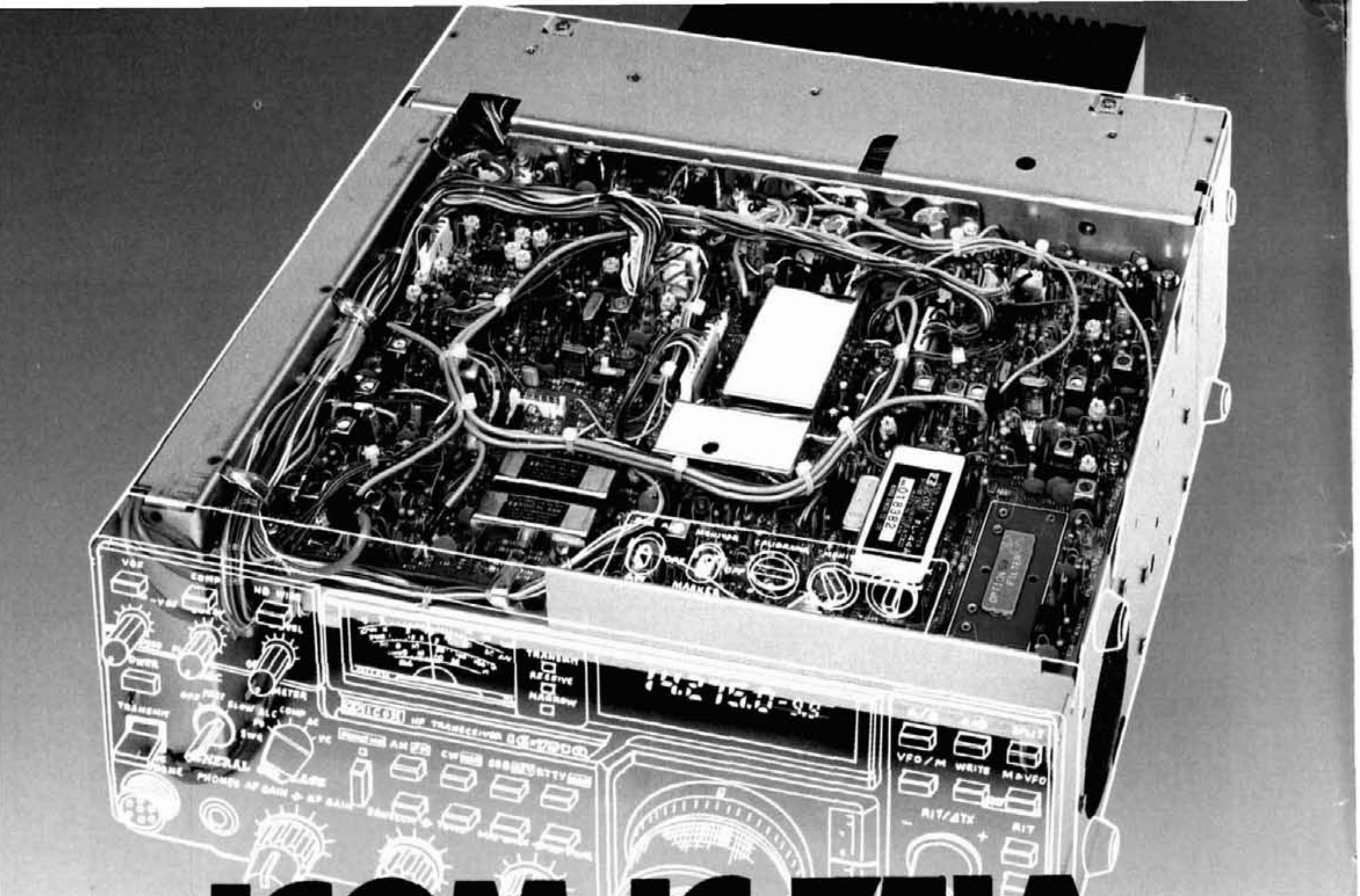

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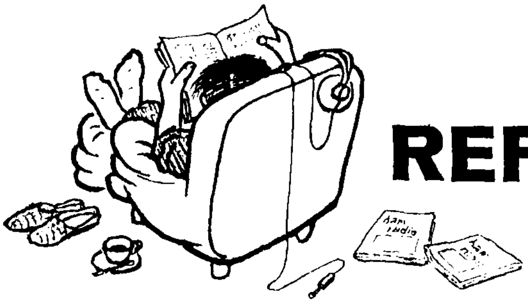

REFLECTIONS

a sentimental technocrat speaks

Thanks to the rapid evolution of electronic technology, Amateur Radio has seen significant changes during the past few years. While many of us fully endorse this advancement of the radio art, some of us are hopelessly sentimental technocrats who sense, over time, a qualitative change for the worse.

Therefore, I hereby submit my opinions on a wide range of issues confronting Amateur Radio. You won't find any engineering measurements, quantified results, or empirical thinking — just unabashed emotionalism. Some of it might be totally wrong. But that's OK — this is a guest editorial, not a technical article. Besides, there comes a time when a guy's got to say what he really thinks!

I've divided my list of issues into two parts: the stuff I don't like and the stuff I do like. "Stuff," by the way, can be anything. Nothing is too sacred for scrutiny.

I really don't like:

PLL synthesizers, radios with memories, plastic cabinets, RCA jacks, circuit boards that disintegrate when they're touched, aluminum capacitors, fm, antenna traps, monolithic radios, on-board rf white noise generators (i.e., microprocessors), cable TV connectors, computer-generated QSL cards, articles that prove Yagis better than quads (even if they're right), FCC dockets (that's right — *all* of them), the Woodpecker, consumer electronics (Have you listened to your high-tech digital readout clock radio lately? I bought one because I like to wake up to music rather than a buzzer. But with my clock radio, I can't tell the difference!), multiple-choice code exams, profanity on the air, anti-antenna ordinances, cable TV "installation" charges, the technical quality of cable TV, fm stereo separation on cable systems, cable TV customer service, 2-meter video channels on cable systems, anything with 75-ohm impedance, disassociation of call districts, lamp dimmers, and the notion that the electromagnetic spectrum exists exclusively for commercial use.

On the other hand, I really do like:

Station logs, any radio component made from ceramic, glass, copper, or silver; oil-filled capacitors (toxic or not), vacuum variable capacitors, open-wire transmission lines, wire beam antennas (double extended zepps, stacked, phased, and fed with open-wire line), old QSL cards, old "How's DX?" columns (the kind with the grass-thatched shack, palm tree, and precarious dipole . . . where did the romance go?), Jeeves cartoons, the old smaller-sized *ham radio* and *QST* magazines (In high school I could hide them under my history book. How can kids hide them nowadays?); old E. F. Johnson, National, Collins, and Hammarlund radios; new radios built for radio performance, front panels that look like they belong on radios instead of computers, moonbounce, really big quads, astronomically large parabolas, computerized RTTY (Here's where a computer in the shack makes sense. Remember those noisy old electromechanical clunkers?), anything homebrew, GaAs LNAs, prop-pitch motors, PTO oscillators, houses built around the ham shack, XYLs who really do understand, kids who *don't* sneak ham magazines into history class, tubes, FETs (they're more like tubes than bipolars), volunteer examinations (taking the old exams was like visiting the Spanish Inquisition), mountain-top QTHs, analog clocks in the shack (especially the 24-hour brass ship's clocks with chimes), multicolored great circle maps *not* centered on Kansas (somebody in Kansas sure has a lot of clout), Silicon Valley and New York-area surplus dealers, *very* expensive linear amplifiers, high-dynamic range anything, low-noise anything, high-gain anything, anything simple yet adequate, anything slightly more complicated yet outstanding, two miles of buried No. 8 copper wire, full-size 160-meter antennas (they work on 80 as well), antennas too high for W2PV, receivers that confound W7ZOI (I'm still waiting for that day), my copy of Terman's *Radio Engineer's Handbook*, the W6GO QSL list, W6SAI's columns (he *really* likes tubes), ham dealers who sell used parts (good stuff, cheap), big heavy rigs with rf ammeters, Smith charts, swap meets (lots of good stuff, cheap), and finally, magazines crazy enough to publish this.

Robert J. Zavrel, Jr., W7SX
Tucson, Arizona

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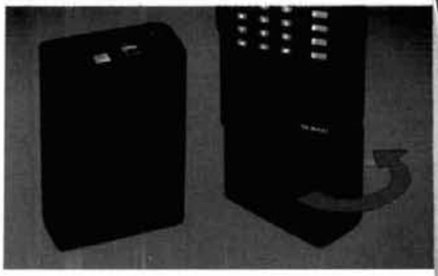
TH-205AT

Affordable 5-watt hand-held transceiver. Ultimate Affordability!

It's here now! The affordable, "Kenwood Quality" hand-held transceiver. Standard features include a large, easy-to-read LCD display, wide-range power requirements (operates on 7.2 VDC–16 VDC), 3-channel memory, built-in battery saver circuit, and, when operated on 12 VDC, a robust five watts of power! The die-cast metal rear panel/heat sink assures cool, reliable operation. Receiver frequency coverage from 141–163 MHz is also standard—you can even listen to the "weather channels" at 162.40 or 162.55 MHz!

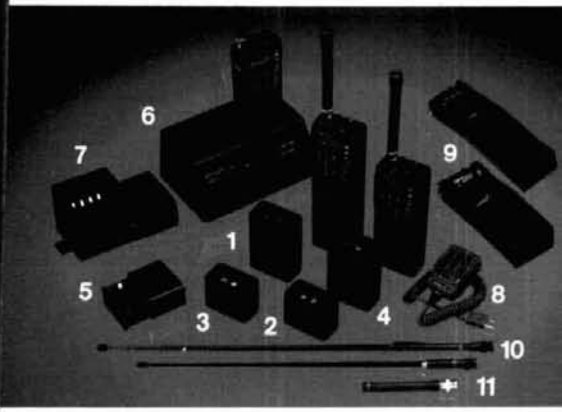
- Monitor switch—to check frequency when PL encode/decode switch is on.
- Extended frequency coverage for certain MARS and CAP operations.
- 3 memory channels store frequency and offset. And so easy to use! Simply press the memory channel number to recall your favorite channels!
- Night light, offset/reverse.
- 16-key DTMF pad for repeater autopatch is standard.



- NEW! Twist-Lok Positive-Connect™ battery case. A wide range of quick-change commercial duty battery packs are available.

- 12 VDC input terminal—allows direct mobile or external power supply operation. When 12 VDC is applied, power output increases to **5 watts!**

- Heavy-duty final amplifier and heat sink. The die-cast rear panel assures reliable operation. With the optional 12-volt PB-1 battery pack, the TH-205AT provides 5 W output. The standard 8.4 volt PB-2 provides 2.5 W output. (500 mW low power).
- Large, easy-to-read LCD display. Frequency, offset, memory channel, TX, RX, and battery indicator.
- Frequency UP/DOWN keys. Used to select frequency or scanning direction.
- Scan function key.
- Automatic battery saver circuit extends battery life. No buttons to push!
- Supplied accessories include: Rubber flex antenna, belt hook, 8.4 V, 500 mAH NiCd battery pack, wall charger.



Optional Accessories:

1) PB-1 12 V 800 mAH NiCd batt. pack (5 W output). **2)** PB-2 8.4 V 500 mAH NiCd batt. pack (2.5 W output). **3)** PB-3 7.2 V 800 mAH NiCd batt. pack (1.5 W output). **4)** PB-4 7.2 V 1600 mAH NiCd batt. pack (1.5 W output). **5)** BT-5 AA manganese/alkaline battery case. **6)** BC-7 Rapid charger for PB-1, 2, 3, or 4. **7)** BC-8 Compact battery charger **8)** SMC-30 Speaker microphone. **9)** SC-12, SC-13 Soft cases. **10)** RA-3, RA-5 Telescoping antennas. **11)** RA-8B StubbyDuk antenna • TSU-3 CTCSS encode/decode unit • VB-2530 2 m, 25 W RF power booster • LH-4, LH-5 Leather cases • MB-4 Mobile bracket • BH-5 Swivel mount • PG-2V DC cable • PG-3C Filtered cigar lighter cord.

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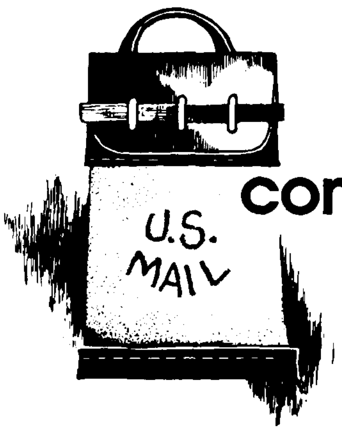

comments

code tests

The following is a copy of a letter addressed to the FCC by W.G. Welsh, who kindly shared it with us. — Ed.

I am pleased that you separated Technician and General written examination material. I had suggested this step in two previous letters I wrote to you about 30 years ago. I hope you will continue this trend and separate code tests. At present, Novice and Technician applicants must pass element 1-A, which is 5 WPM. At present, General and Advanced applicants must pass element 1-B, which is 13 WPM. The Extra Class requirement is element 1-C at 20 WPM.

I believe a separate code test requirement is appropriate for each class of license. I think the code test speeds would be appropriate at 4 (Novice), 8 (Technician), 12 (General), 16 (Advanced), and 20 (Extra Class).

Most beginning Novices send code about [at] 3 WPM. A code test at 4 WPM is more appropriate to their initial needs. The receiving test should be restored to forward-reading plain language text that just includes letters. Punctuation marks, numerals, and work signs were previously restricted to the sending test, which should still be suitable. The international requirement is that all applications for Amateur Radio operator licenses, that involve operating privileges below 30 MHz, must prove their ability to receive (by ear) and to send (by hand) the International Morse Code. I believe that this requirement can be met more easily at the Novice level than in the VEC (Technician through Extra Class) test program.

The jump from 5 to 13 WPM is drastic. Allowing candidates to move up in increments of 4 WPM should be beneficial. The proposed 8 and 12 WPM Technician and General code test requirements should help increase upgrades.

Similarly, the difference between 13 and 20 WPM is pronounced. The proposed 16 WPM Advanced code test requirement would be more conducive to upgrading to the 20-WPM Extra Class requirement.

Each step up in license grade entails increased operating spectrum wherein code may be used. It seems reasonable that the associated code test speed requirements should be separate and evenly stepped from the lowest to the highest license.

I have conducted Amateur Radio operator licensing courses every year since 1948. I am very active helping students. I know their problems and needs.

I hope you will give this matter prompt attention.

William G. Welsh, W6DDB, Burbank, California 91504-3297.

KLM balun

Dear HR:

Over the past year there it has been stated that some of our antennas (the 11X, 13LBA, and 16 LBX for 2 meters and the 14X and 22LBX for 220 MHz) had extremely high VSWR because the baluns were of the wrong length. These antennas are very sensitive; their leads must be as short as possible and balanced.

To remove any possibility of connecting the antennas improperly, we have developed a connector that is being supplied on all new antennas. In addition, anyone who has one of the antennas identified above may call us, toll-free, at 1-800-538-2140 (outside California) or 408-779-7363 (collect, from within California), and we'll be happy to send a connector free of charge.

W.M. Scott
Mirage/KLM Communications Equipment, Inc.
P.O. Box 1000
Morgan Hill, California 95037

novice calling frequency

Dear HR:

The 10-meter Novice band still needs an easy-to-remember calling frequency. I suggest making 28.1010 MHz the Novice 10-meter calling frequency. So, get in 28.1010 and give a call!

Henry Hampel, KA0TUP, St. Louis, Missouri 63116

elmers at work

Dear HR:

Received my *ham radio* today and as usual found some interesting reading. I think your new column, "Elmer's Notebook," by Tom McMullen, W1SL, can become a very useful part of the magazine, depending upon how it's handled.

We've established an Elmer committee in our club. Committee members are available to help out new Novices, and the committee has a supply of equipment to lend to the new hams until they can get some of their own.

In checking back on about 100 Novices licensed in the past several years, we found that may of them never became active. By actively working with new Novices as they become licensed, perhaps we'll be able to keep them interested.

George A. Diehl
Chatham, New Jersey 07928-1179

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MFJ's BEST 300 WATT TUNER HAS A CROSS-NEEDLE METER THAT READS SWR, FORWARD AND REFLECTED POWER – ALL AT A GLANCE

MFJ-949C
$149⁹⁵

MFJ's best 300 watt tuner is now even better!
The MFJ-949C all-in-one Deluxe Versa Tuner II gives you a tuner, cross-needle SWR/Wattmeter, dummy load, antenna switch and balun in a compact cabinet. You get quality conveniences and a clutter-free shack at a super price.

A cross-needle SWR/Wattmeter gives you SWR, forward and reflected power -- all at a single glance. SWR is automatically computed with no controls to set. 30 and 300 watt scale on easy-to-read 2 color lighted meter (needs 12 V).

A handsome black brushed aluminum cabinet matches all the new rigs. Its compact size (10 x 3 x 7 inches) takes only a little room.

You can run full transceiver power output -- up to 300 watts RF output --and match coax, balanced lines or random wires from 1.8-30 MHz. Use it to tune out SWR on dipoles, vees, long wires, verticals, whips, beams and quads.

A 300 watt 50 ohm dummy load gives you quick tune ups and a versatile six position antenna switch lets you select 2 coax lines (direct or thru tuner), random wire or balanced line and dummy load.

A large efficient airwound inductor -- 3 inches in diameter -- gives you plenty of matching range and less losses for more watts out. 100 volt tuning capacitors and heavy duty switches give you safe arc-free operation. A 4:1 balun is built-in to match balanced lines.

Order your convenience package now and enjoy.

MFJ 12/24 HOUR LCD CLOCKS

MFJ-108 $19.95 **MFJ-107 $9.95**

Huge 5/8 inch bold black LCD numerals make these 24 hour LCD clocks a must for your ham shack. Choose from a dual clock that displays UTC and local time or the single unit that displays 24 hour time.

Mounted in a brushed aluminum frame, these clocks feature 5/8 inch LCD numerals and a sloped face for easy across the room reading. Both also feature easy set month, day, hour, minute and second functions that can be operated in an alternating time-date display mode. MFJ-108, 4½x1x2 inches; MFJ-107, 2¼x1x2 inches. Battery included.

MFJ-962B VERSA TUNER III

MFJ-962B $229.95

Run up to 1.5KW PEP and match any feedline continuously from 1.8 to 30 MHz: coax, balanced line or random wire.

Lighted Cross-needle Meter reads SWR, forward and reflected power in one glance. Has 200 and 2000 watt ranges. 6 position antenna switch handles 2 coax lines, random wire and balanced lines. 4:1 balun. 250 pf, 6 kv variable capacitors. 12 position ceramic Inductor switch. Smaller size matches new rigs: 10¾ x 4½ x 14 7/8 inches. Flip stand for easy viewing. Requires 12V for light.

MFJ RANDOM WIRE TUNER

MFJ-16010
$39.95

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MFJ-815
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MFJ's cross-needle SWR/Wattmeter gives you SWR, forward and reflected power -- all at a single glance! SWR is automatically computed -- no controls to adjust. Easy-to-use push buttons select three power ranges that give you QRP to full legal limit power readings. Reads 20/200/2000 W forward, 5/50/500 W reflected and 1:1 to 1:5 SWR on easy-to-read two color scale. Lighted meter needs 12 V. ±10% full scale accuracy. 6½x3¼x4½ inches.

COMPACT SPEAKER

MFJ-280 $18.95

Mobile speaker. Tilt bracket on magnetic base. 3½ mm phone plug. Use with 8 and 4 ohm impedances. Handles 3 watts audio.

HANDHELD TELESCOPING ANTENNAS WITH BNC

MFJ-1710, $9.95, 3/8 wave 2 meter. Pocket clip. 5¾" - 24½".
MFJ-1712, $14.95, ¼ wave 2 meter; 5/8 wave 440 MHz, 7¼" - 19".
MFJ-1714, $16.95, ½ wave 2 meter. End-fed halfwave dipole. Shorter, lighter, more gain, less stress than 5/8 wave mounted on handheld. When collapsed it performs like rubber duck.

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MFJ-262
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MFJ DELUXE ELECTRONIC KEYER

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ANTENNA CURRENT PROBE

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- **Pinpoint RF leakage** in shielded enclosures.
- **Locate best place** for mobile antenna.
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Monitors RF current. 1.8-30 MHz. Has sensitivity, bandswitch, tune controls, telescoping antenna for field strength meter. 4x2x2 inches.

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MFJ . . . making quality affordable

design a no-tune amplifier
with your personal computer

Try a broadband approach for instantaneous coverage

When a friend asked how a no-tune amplifier is designed, I had to say I really didn't know. It seemed, at the time, that if one were to use a low-Q circuit to convert the calculated plate load impedance to some other value — say 50 ohms — and then follow it with a symmetrical multi-section low-pass filter for that impedance, a semblance of a "no-tune" amplifier could be designed. Because some circuit analysis would appear to be necessary, it occurred to me that a personal computer could be an important tool in such a project.

To be truly "no-tune," an amplifier should be capable of operating over its intended range without being retuned; that is, its efficiency and power output should not be degraded. An rf power amplifier must have a tank circuit of sufficient Q to maintain a sinusoidal voltage on the plate, but the broadband requirement would seem to be a tank of low Q. There are economic factors to consider (how many components? what quality?) and, as it developed, questions about how many unknown currents would have to be calculated; this has a direct bearing on the complexity of the calculations.

The design described here developed from the original assumptions of a low-Q tank followed by a Chebyshev five-element low-pass filter. Partial circuits are shown in **figs. 1A** and **1B**.

tank design

Two obvious possibilities for the tank design are Pi-section and L-section tank circuits. In the former, Q is selectable (down to some minimum value), and in the latter, it usually isn't. Because the no-tune concept requires a lower Q, and because there's one less component, the L-section was chosen. This particular design is based on an amplifier with two 3-500Zs whose plate load resistance has been calculated as 2080 ohms. The design center frequency is 14.2 MHz. The amplifier also has plug-in tank and filter circuits (shades of World War II!), but that bears little on the design calculations.

L-section calculations

The algebraic equations for the tank circuit design, available from several sources,[1] are:

$$X_L = \sqrt{R1 \cdot R2 - R2^2}, \text{ and}$$
$$X_C = (-R1 \cdot R2) / X_L) \text{ for } R1 > R2$$

A small BASIC program for computing the values is provided in **fig. 2**. Although Q isn't mentioned in the program, it can be calculated easily in this case by:

$$Q = X_L / R2 = 318.6/50 = 6.372$$

The value calculated is adequately low for our purposes, but too low to be used without some kind of a follow-up filter; one wouldn't build an amplifier with only these characteristics, however. **Figure 3** shows the values of Q for L-sections that convert to 50 ohms. Coincidentally, they're the minimum values obtainable with the Pi-section.

By W. J. Byron, W7DHD, P.O. Box 2789, Sedona, Arizona 86336

the low-pass filter

Low-pass filters can be designed either from scratch or from tables produced by others.[2] The first filter

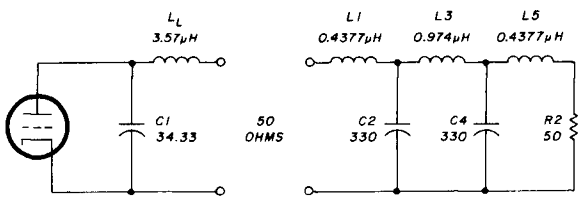

fig. 1A. Basic matching circuit: the L-section on the left transforms 2080 to 50 ohms; the symmetrical low-pass filter on the right operates at 50 ohms input and output, and has a cut-off frequency of 16.38 MHz.

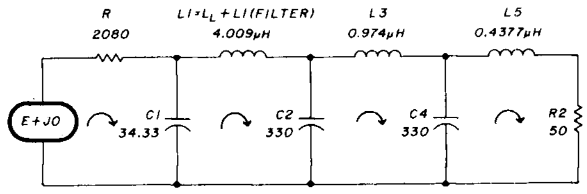

fig. 1B. Basic matching circuit: inductances L_L and L1 are combined into a new inductance, L1. The four loop currents used in deriving the equations in the text are shown with their orientation.

selected has the following characteristics:
f (-3 dB): 1.638 MHz
f(-20 dB): 2.349 MHz
f(-50 dB): 4.48 MHz
L1, L5 (μH): 4.377
C2,C4 (pF): 3300
L3 (μH): 9.747

These numbers represent the values necessary for the listed frequencies. The table from which this filter came lists filters designed around "standard-value" components — in this case, the 3300-pF capacitors. As a result of this compromise, the VSWR of the network terminated by 50 ohms will be 1.06. The component values for a 10X increase in frequency will be one tenth of the values shown for the capacitors and inductances. The latter values were used for the first investigation. Another filter was designed from scratch (with the aid of the W1JR/WA1GRC CAD program[3]); the results are also presented here. It was selected to have the same 16.38-MHz cutoff as the filter above. Both have the Chebyshev response.

The amplifier's performance can be simulated by actually calculating all the voltages and currents around the circuit. The combination of the L-section and five-element filter plus the 50-ohm terminating resistor makes a four-unknown set of equations. Power output is $R2 \cdot I_4^2$. The plate voltage is indicat-

```
10 REM  R1 MUST BE LARGER THAN R2
20 INPUT "ENTER THE LARGER RESISTANCE";R1
30 INPUT "ENTER THE SMALLER RESISTANCE";R2:PRINT
40 XL = SQR(R1*R2-R2^2)
50 XC = -(R1*R2)/XL
60 PRINT "XL = ";XL;" Ohms, and""   XC = ";XC; " Ohms":PRINT
70 INPUT "ENTER THE FREQUENCY IN MHZ";F:PRINT
80 F = F*1000000!
90 W = 2*3.14159*F
100 PRINT "L = ";(XL/W)*1000000!;"  Microhenrys"
110 PRINT "C = ";-(1/(W*XC))*1E+12;" Picofarads"
120 END
RUN
ENTER THE LARGER RESISTANCE? 2080
ENTER THE SMALLER RESISTANCE? 50

XL =  318.5906  Ohms, and   XC = -326.4377  Ohms

ENTER THE FREQUENCY IN MHZ? 14.2

L =  3.570797   Microhenrys
C =  34.33459  Picofarads
Ok
```

fig. 2. BASIC program for computing L-section elements. The values shown for L and C are for the example described in the text.

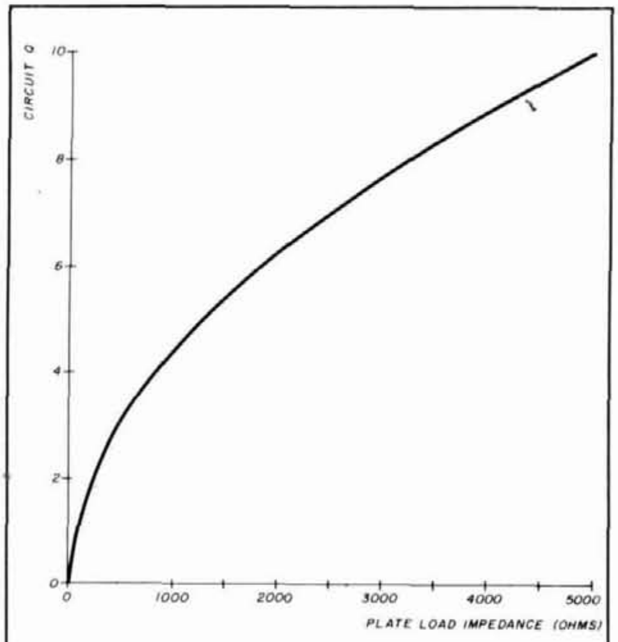

fig. 3. The values of Q available for L-sections and the minimum values available for Pl-sections. The curve applies only to sections that transform impedances to 50 ohms.

ed as "E" in **fig. 1B**. Four equations are needed to solve for the four currents (Kirchoff's loops require this). All have complex coefficients. The equations below are in simplified form, but they're the ones that must be solved:

$$I_1(R_p + X_{C1}) - I_2(0 + X_{C1}) + I_3(0 + 0) + I_4(0 + 0) = (E + j0) \quad \textbf{(1A)}$$

$$-I_1(0 + X_{C1}) + I_2(0 + X_{C1} + X_{L1} + X_{C2}) - I_3(0 + X_{C2}) + I_4(0 + 0) = (0 + j0) \quad \textbf{(1B)}$$

$$I_1(0 + 0) - I_2\ (0 + X_{C2}) + I_3\ (0 + X_{C2} + X_{L3} + X_{C4}) - I_4(0 + X_{C4}) = (0 + j0) \quad \textbf{(1C)}$$

$$I_1(0 + 0) + I_2(0 + 0) - I_3(0 + X_{C4}) + I_4(R_2 + X_{L5} + X_{C4}) = (0 + j0) \quad \textbf{(1D)}$$

A short program following the simplified form above is used to evaluate the currents. The only real numbers in the equations are R_p, R_2, and E, plus the leading zeros inside the parentheses. All other numbers are imaginary. The X_L's are intrinsically positive, and the X_C's are negative ($X_C - j/(2\pi fC)$. The "coefficients" program is listed in **fig. 4. Lines 100** through **240** provide a listing of the reactances, which were useful during the design. They can be eliminated if desired, because the coefficients themselves are produced in **lines 250** through **510** (including, of course, **lines 10** through **90**). An example of the output of the coefficients program is shown in **fig. 5**.

Now the equations must be solved. One of the best

```
10 REM: SAVED AS "CHEB5"
20 C1 = 37!*1E-12
30 L1 = 4.009*.000001
40 C2 = 330*1E-12
50 L3\= .9747*.000001
60 C4 = 330*1E-12
70 L5 = .438*.000001
80 R1 = 2080
90 R2 = 50
100 LPRINT"FREQ    XC1-OHMS    XL1-OHMS    XC2-OHMS    XL3-OHMS    XC4-OHMS     XL5-OH
MS"
110 LPRINT"____    ________    ________    ________    ________    ________    _______
_"
120 LPRINT
130 A$ = "##.##  ####.##    ####.##    ####.##    ####.##    ####.##    ####.##"
140 FOR F =14.2 TO 14.22 STEP .02
150 W = 2*3.14159*F*1000000'
160 XC1 =-1/(W*C1)
170 XL1 = W*L1
180 XC2 =-1/(W*C2)
190 XL3 = W*L3
200 XC4 =-1/(W*C4)
210 XL5 = W*L5
220 LPRINT USING A$;F,XC1,XL1,XC2,XL3,XC4,XL5
230 NEXT F
240 LPRINT:LPRINT
250 LPRINT"       COEFFICIENTS FOR GAUSS-JORDAN ELIMINATION"
260 LPRINT
270 LPRINT"  REAL    ,  IMAG    REAL , IMAG    REAL , IMAG    REAL , IMAG    REAL
 , IMAG"
280 LPRINT"_______________  ____________  ____________  ____________  _____
_________"
290  B$=  " #####.##,####.##  ###.##,###.##  ###.##,###.##  ###.##,###.##  ####.
##,###.##"
300 FOR F =14.2 TO 14.22 STEP .02
310 W = 2*3.14159*F*1000000'
320 XC1 =-1/(W*C1)
330 XL1 = W*L1
340 XC2 =-1/(W*C2)
350 XL3 = W*L3
360 XC4 =-1/(W*C4)
370 XL5 = W*L5
380 R1 = 2080'
390 R2 = 50!
400  A1 = R1:B1=XC1:A2=0:B2=-XC1:A3=0:B3=0:A4=0:B4=0:A5=3000:B5=0
410  S1=0:T1=-XC1:S2=0:T2=XC1+XL1+XC2:S3=0:T3=-XC2:S4=0:T4=0:S5=0:T5=0
420  U1=0:V1=0:U2=0:V2=-XC2:U3=0:V3=XC2+XL3+XC4:U4=0:V4=-XC4:U5=0:V5=0
430  Y1=0:Z1=0:Y2=0:Z2=0:Y3=0:Z3=-XC4:Y4=R2:Z4=XC4+XL5:Y5=0:Z5=0
440 LPRINT"FREQUENCY =";F;"MHz"
450 LPRINT USING B$; A1,B1,A2,B2,A3,B3,A4,B4,A5,B5
460 LPRINT USING B$; S1,T1,S2,T2,S3,T3,S4,T4,S5,T5
470 LPRINT USING B$; U1,V1,U2,V2,U3,V3,U4,V4,U5,V5
480 LPRINT USING B$; Y1,Z1,Y2,Z2,Y3,Z3,Y4,Z4,Y5,Z5
490 LPRINT"------------------------------------------------------------"
500 NEXT F
510 END
```

fig. 4. BASIC program for calculating the coefficients for the Gauss-Jordan elimination solutions.

FREQ	XC1-OHMS	XL1-OHMS	XC2-OHMS	XL3-OHMS	XC4-OHMS	XL5-OHMS
14.20	-302.92	357.69	-33.96	86.96	-33.96	39.08
14.22	-302.50	358.19	-33.92	87.09	-33.92	39.13

COEFFICIENTS FOR GAUSS-JORDAN ELIMINATION

REAL , IMAG	REAL , IMAG	REAL , IMAG	REAL , IMAG	REAL , IMAG
FREQUENCY = 14.2 MHz				
2080.00,-302.92	0.00,302.92	0.00, 0.00	0.00, 0.00	3000.00, 0.00
0.00, 302.92	0.00, 20.80	0.00, 33.96	0.00, 0.00	0.00, 0.00
0.00, 0.00	0.00, 33.96	0.00, 19.04	0.00, 33.96	0.00, 0.00
0.00, 0.00	0.00, 0.00	0.00, 33.96	50.00, 5.11	0.00, 0.00
FREQUENCY = 14.22 MHz				
2080.00,-302.50	0.00,302.50	0.00, 0.00	0.00, 0.00	3000.00, 0.00
0.00, 302.50	0.00, 21.78	0.00, 33.92	0.00, 0.00	0.00, 0.00
0.00, 0.00	0.00, 33.92	0.00, 19.25	0.00, 33.92	0.00, 0.00
0.00, 0.00	0.00, 0.00	0.00, 33.92	50.00, 5.22	0.00, 0.00

fig. 5. Sample of the output of the "Coefficients" program. The solution is for two frequencies, 14.2 and 14.22 MHz. The reactances are above, and the coefficients are below.

techniques available is known as the Gauss-Jordan elimination. The main program, listed in **fig. 6**, is taken from what is probably the best source of scientific and engineering programs currently available.[4] Its input requires that the coefficients be entered in order; the first real number of the first equation (R_p in this case) through the imaginary component of the last constant (j0 of the right-hand side of the equation for I_4.

solving the problem

The first attempt was to use the values for the calculated L-section above, followed by the filter from reference 2. Because the L-section has an inductor as the output and the filter was selected to have an inductor as an input element (one can also choose a filter with a capacitive input), these were combined into one inductor (see **fig. 1B**). With the values so determined, they were typed into the coefficients program. It will yield pages of coefficients, depending on the range and increments (steps) one chooses in the FOR-NEXT loops.

As it turned out, although an amplifier constructed around these components would have worked moderately well, it would show the effects of the compromises in the filter designed around standard values. By sweeping the frequency, it was easy to see that the L-section capacitor was too small. Nevertheless, the capacitor would have delivered 90 percent of the power delivered by the matched L-section alone. The next step was to "tune" C1 by modifying the coefficients program to fix the frequency at 14.2 MHz, and then vary the value of C1. The results of this are shown in **fig. 7**. The output follows the typical resonance response, just as if the capacitor were tuned by hand in a real amplifier. From this plot, it's evident that the value for C1 should be changed from 34 to 37 pF. The results are shown in **fig. 8**; also shown is the response of an L-section and filter designed for that use, with exact-size components employed.

The output of the Gauss-Jordan routine, an example of which is shown in **fig. 9**, gives currents in both polar and Cartesian coordinates. The "magnitude" is the same as a scalar value. If it appears as, say, the current in R2, there's no complication; use it as it stands. If it's necessary to know what current is flowing in C2, however, one must take the vector difference between the two currents flowing in "opposite" directions through C2. The source voltage for these problems is arbitrary; I've specified it as E + j0. All other listed phase angles are referenced to that voltage. They're important only when the design requirement might be a specific phase angle. Here it's not a design criterion — but as described above, the phase angles must be considered when determining the ratings of components used in the amplifier.

sizing components

The curves of **fig. 7** were calculated by assuming an ac plate voltage of 3000. The power outputs were between 900 and 1100 watts. It requires just over 3500 volts to achieve 1500 watts output. When 3500 + j0 is used for the input to the program, I_4 reaches 5.39

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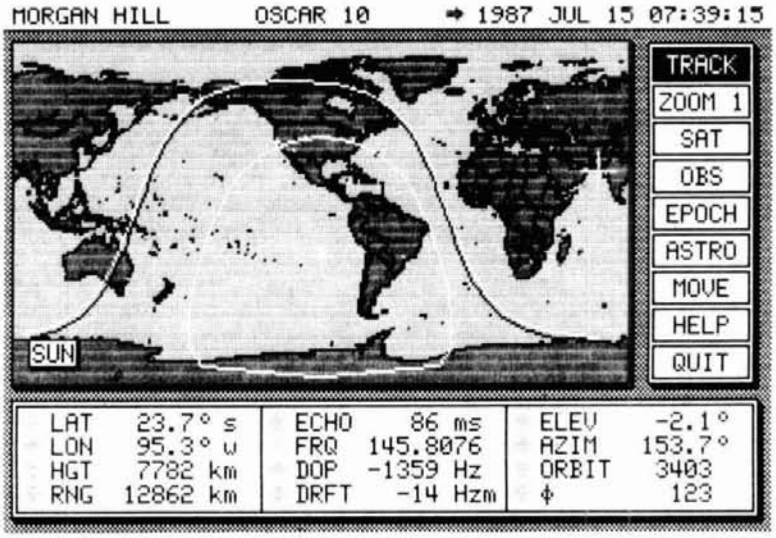
fig. 6. The Gauss-Jordan elimination routine in BASIC. (Reproduced from *BASIC Programs for Scientists and Engineers*, by Alan R. Miller, copyright 1982, SYBEX, Inc., Alameda, California 94501. All rights reserved.)

```
10 REM SIMULTANEOUS SOLUTION OF COMPLEX EQUATIONS
20 REM BY THE GAUSS-JORDAN ELIMINATION TECNIQUE
30 REM
40 A$ = "##.###^^^^ "
50 B$ = " = ##.###^^^^"
60 C$ ="  ##.#####   ##.#####   ##.#####   ###.#####"
70 M1% = 8
80 DIM Z(8),A(8,8),C1(8),W(8,1),B(8,8),I2%(8,3)
90 DIM D4(4,4),D5(4,4),V(4,2)
100 P8 = 180!/3.14159
110 REM
120 REM
130 REM
140 GOSUB 410:REM INPUT ROUTINE
150 GOSUB 790: REM GAUSS-JORDAN ROUTINE
160 REM
170 IF (N1%>5) THEN 250
180   PRINT "        MATRIX CONSTANTS"
190 FOR I% = 1 TO N1%
200   FOR J% = 1 TO N2%
210     PRINT USING A$;A(I%,J%);
220   NEXT J%
230   PRINT USING B$; Z(I%)
240 NEXT I%
250 PRINT
260 IF (E1% = 1) THEN 400
270 PRINT"    REAL      IMAGINARY     MAGNITUDE     ANGLE"
280 PRINT
290 FOR I% = 1 TO N2%/2
300   J% = 2*I% - 1
310   R2 = C1(J%)
320   I6 = C1(J% + 1)
330   M3 = SQR(R2*R2+I6*I6)
340   IF (R2>0) THEN A1 = ATN(I6/R2)*P8
350   IF (R2 = 0) THEN A1 = SGN(I6)*90
360   IF (R2<0) THEN A1 = ATN(I6/R2)*P8+180
370 PRINT USING C$;R2,I6,M3,A1
380 NEXT I%
390 PRINT
400 GOTO 140: REM NEXT SET OF EQUATIONS
410 REM
420 REM INPUT DATA
430 REM
440 INPUT"  HOW MANY EQUATIONS";N1%
450 IF(N1%>(M1%/2)) THEN 440
460 IF(N1%<2) THEN 1880
470 N2% = N1%
480 FOR I% = 1 TO N1%
490   PRINT "EQUATION";I%
500   K% = 0
510   L% = 2*I% - 1
520   FOR J% = 1 TO N1%
530     K% = K% + 1
540     PRINT"REAL ";J%;"  ";
550     INPUT D4(I%,J%)
560     A(L%,K%) = D4(I%,J%)
570     A(L%+1,K%+1) = D4(I%,J%)
580     K% = K% + 1
590     PRINT"IMAG ";J%;"  ";
600     INPUT D5(I%,J%)
610     A(L%,K%) = -D5(I%,J%)
```

```
620      A(L%+1,K%-1) = D5(I%,J%)
630    NEXT J%
640    INPUT"REAL CONST "; V(I%,1)
650    Z(L%) = V(I%,1)
660    INPUT"IMAG CONST ";V(I%,2)
670    Z(L%+1) = V(I%,2)
680 NEXT I%
690 PRINT: REM PRINT ORIGINAL MATRIX
700 FOR I% = 1 TO N1%
710    FOR J% = 1 TO N2%
720      PRINT D4(I%,J%);D5(I%,J%);
730    NEXT J%
740    PRINT V(I%,1);V(I%,2)
750 NEXT I%
760 N1% = 2*N1%
770 N2% = N1%
780 RETURN: REM FROM INPUT ROUTINE
790 REM GAUSS-JORDAN ROUTINE
800 REM
810 REM
820 E1% = 0
830 I5% = 1
840 N3% = 1
850 FOR I% = 1 TO N2%
860    FOR J% = 1 TO N2%
870      B(I%,J%) = A(I%,J%)
880    NEXT J%
890    W(I%,1) = Z(I%)
900    I2%(I%,3) = 0
910 NEXT I%
920 D3 = 1
930 FOR I% = 1 TO N2%
940 REM
950 REM
960 REM
970 B1 = 0
980 FOR J% = 1 TO N2%
990    IF (I2%(J%,3)=1) THEN 1080
1000    FOR K% = 1 TO N2%
1010      IF (I2%(K%,3)>1) THEN 1850
1020      IF (I2%(K%,3)=1) THEN 1070
1030      IF (B1>=ABS(B(J%,K%))) THEN 1070
1040      I3% = J%
1050      I4% = K%
1060      B1 = ABS(B(J%,K%))
1070 NEXT K%
1080 NEXT J%
1090 I2%(I4%,3) = I2%(I4%,3)+1
1100 I2%(I%,1) = I3%
1110 I2%(I%,2) = I4%
1120 REM
1130 IF (I3% = I4%) THEN 1270
1140 D3 = -D3
1150 FOR L% = 1 TO N2%
1160    H1 = B(I3%,L%)
1170 B(I3%,L%) = B(I4%,L%)
1180 B(I4%,L%) = H1
1190 NEXT L%
1200     IF (N3%<1) THEN 1270
1210     FOR L% = 1 TO N3%
1220       H1 = W(I3%,L%)
1230       W(I3%,L%) = W(I4%,L%)
1240       W(I4%,L%) = H1
1250     NEXT L%
1260 REM
```



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VSWR	1.5:1
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FEED IMP	50 ohm
BALUN	4:1 coax

MECHANICAL:

ELEMENT LENGTH	13½" max.
BOOM LENGTH	28"
TURN RADIUS	28"
WINDLOAD	2 sq. ft.
WEIGHT	1 lb.
MAST	1½" o.d.
MOUNT	Rear

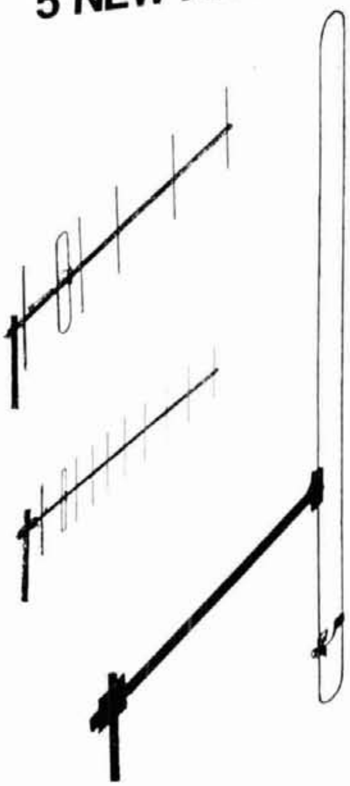
440-10X

ELECTRICAL:

BANDWIDTH	420-460 MHz
GAIN	11.2 dBd
VSWR	1.5:1
F/B	20 dB
BEAMWIDTH	48°
FEED IMP	50 ohm
BALUN	4:1 coax

MECHANICAL:

ELEMENT LENGTH	13½" max.
BOOM LENGTH	64"
TURN RADIUS	64"
WINDLOAD	4 sq. ft.
WEIGHT	1½ lbs.
MAST	1½" o.d.
MOUNT	Rear



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MECHANICAL:

HEIGHT	61"
WEIGHT	2½ lbs.
MAST	1½" o.d.

CJ220

ELECTRICAL:

BANDWIDTH	220-224 MHz
GAIN	1.8 dBd
VSWR	1.5:1
FEED IMP	50 ohms

NO GROUND PLANE REQUIRED

MECHANICAL:

HEIGHT	40"
WEIGHT	2 lbs.
MAST	1½" o.d.

CJ440

ELECTRICAL:

BANDWIDTH	420-470 MHz
GAIN	1.8 dBd
VSWR	1.5:1
FEED IMP	50 ohms

NO GROUND PLANE REQUIRED

MECHANICAL:

HEIGHT	19¼"
WEIGHT	1 lb.
MAST	1½" o.d.

```
1270     P1 = B(I4%,I4%)
1280     D3 = D3*P1
1290     B(I4%,I4%) = 1
1300     FOR L% = 1 TO N2%
1310       B(I4%,L%) = B(I4%,L%)/P1
1320     NEXT L%
1330     IF (N3%<1) THEN 1390
1340     FOR L% = 1 TO N3%
1350       W(I4%,L%) = W(I4%,L%)/P1
1360     NEXT L%
1370 REM
1380 REM
1390     FOR L1% = 1 TO N2%
1400       IF(L1% = I4%) THEN 1500
1410       T = B(L1%,I4%)
1420       B(L1%,I4%) =0
1430       FOR L% = 1 TO N2%
1440         B(L1%,L%) = B(L1%,L%) - B(I4%,L%)*T
1450       NEXT L%
1460       IF (N3%<1) THEN 1500
1470       FOR L% = 1 TO N3%
1480         W(L1%,L%) = W(L1%,L%) - W(I4%,L%)*T
1490       NEXT L%
1500    NEXT L1%
1510 NEXT I%
1520 REM
1530 REM
1540 REM
1550 FOR I% = 1 TO N2%
1560   L% = N2% -I% +1
1570   IF(I2%(L%,1) = I2%(L%,2)) THEN 1650
1580   I3% = I2%(L%,1)
1590   I4% = I2%(L%,2)
1600   FOR K% = 1 TO N2%
1610     H1 = B(K%,I3%)
1620     B(K%,I3%) = B(K%,I4%)
1630     B(K%,I4%) = H1
1640   NEXT K%
1650 NEXT I%
1660 FOR K% = 1 TO N2%
1670   IF(I2%(K%,3)<>1) THEN 1850
1680 NEXT K%
1690 E1% = 0
1700 FOR I% = 1 TO N2%
1710   C1(I%) = W(I%,1)
1720 NEXT I%
1730 IF(I5% = 1) THEN 1870
1740 PRINT
1750 PRINT "     Matrix Inverse"
1760 FOR I%= 1 TO N2%
1770   FOR J% = 1 TO N2%
1780     PRINT USING A$; B(I%,J%);
1790   NEXT J%
1800 PRINT
1810 NEXT I%
1820 PRINT
1830 PRINT"Determinant = ";D3
1840 RETURN: REM IF INVERSE IS PRINTED
1850 E1% = 1
1860 PRINT"ERROR - Matrix is Singular"
1870 RETURN: REM From Gauss-Jordan Subroutine
1880 END
```

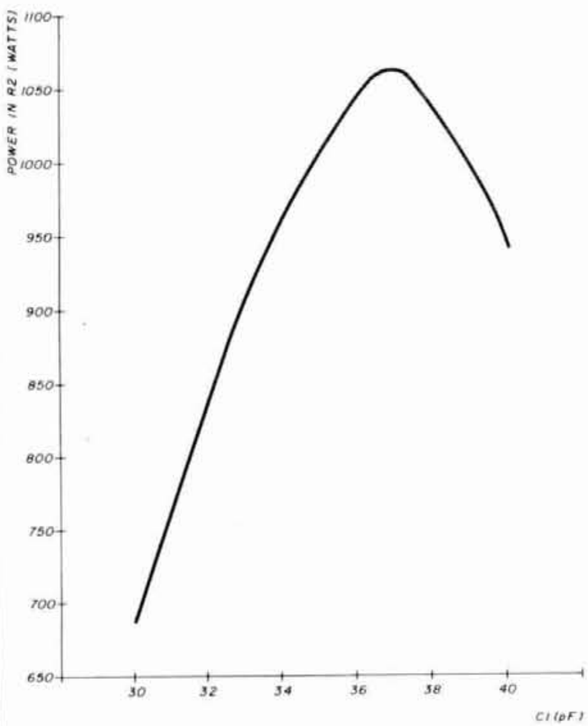

fig. 7. The results of "tuning" C1. The frequency was held constant and C1 was varied from 30 to 40 pF. The vertical scale is the power output $I_4^2 \cdot R2$.

amperes. Thus the calculated power output is about 1453 watts.

What stress is there on the rf amplifier components? The first thing we see is the voltage across C1. Common sense dictates that C1 should have a voltage rating of perhaps 4000 volts. The current through it is less than that flowing through C2. It doesn't seem to be a problem; there's less stress on that capacitor than there would be if the circuit had been a Pi-section. One normally assumes that the heaviest currents are locked up in the tank. But that's not so in this case; the heaviest rf current in the whole system is in the midsection of the filter! It's nearly 10 amperes for E = 3000 peak ac volts, and will be even higher for the 3500 + volts required for maximum legal output power.

Let's calculate the current through C4, the difference between I_3 and I_4. The vector difference is:

$$I_3 = -7.327 + j2.835$$
$$I_4 = 2.356 + j4.844$$
$$I_{C4} = I_3 - I_4 = -9.683 - j2.009$$
$$I_{C4}\ (scalar) = 9.89\ amperes$$

The voltage across C4 is:

$$I_{C4} \cdot (X_{C4}) = (9.89)(34.4) = 340\ volts.$$

Similar calculations can be made for all the other com-

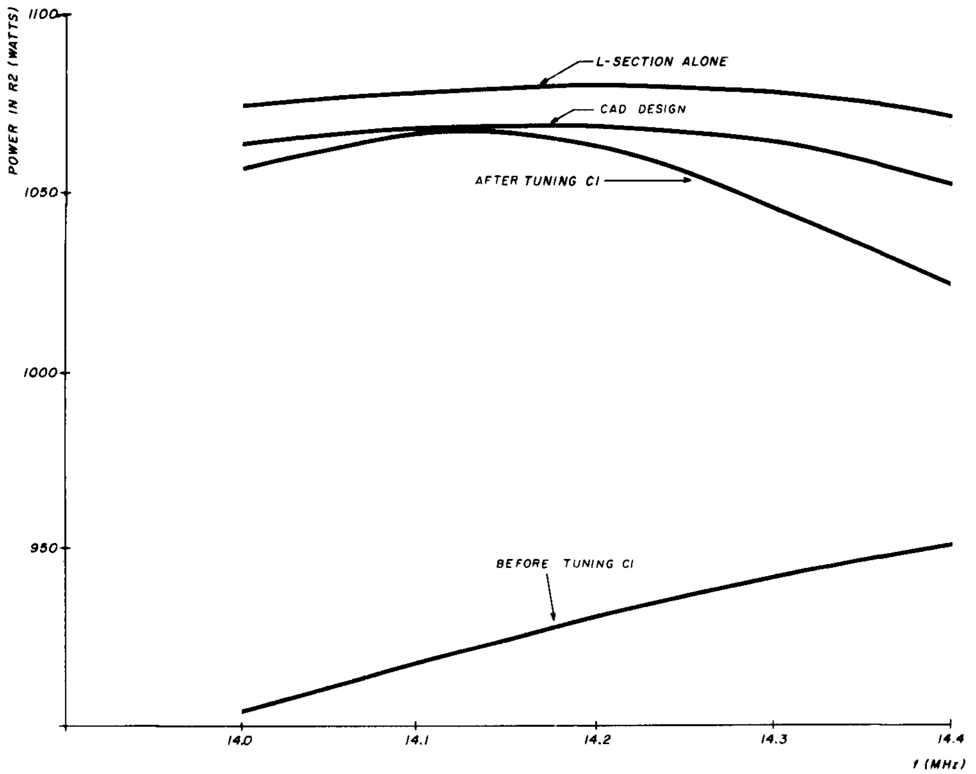

fig. 8. Power output over the 20-meter band using four different configurations. Note the difference between the "before and after tuning" data.

ponents. While "postage-stamp" capacitors could stand the voltage, they wouldn't tolerate the nearly 10-ampere current. Large transmitting-type or homemade capacitors must be used.

The capacitors for this amplifier are constructed from thin copper sheet, aluminum, and 0.030-inch Teflon™ sheet. For the 20-meter band, C2 and C4 are both approximately 300 pF. A homemade two-plate capacitor would measure only a few square inches in area; one side would be the amplifier chassis (or in this case, the bottom plate of the plug-in). All coils are fabricated from No. 10 copper wire. Had this been a Pi-section tank or even a Pi-L tank with the equivalent attenuation ratio of this design (without follow-up filter) the loaded *Q* would have had to be greater than 30, and the tank coil itself would have to be made of 1/4-inch diameter or larger copper tubing.

The same Gauss-Jordan routine may be used to calculate the attenuation at higher frequencies. Use the design values for components in the coefficients program, but change the frequency range and steps. The calculated attenuation at the second harmonic of this design is better than 50 dB; it's plotted in **fig. 10**.

All of the foregoing involves calculations with complex numbers. **Figure 11** contains BASIC routines that

```
2080 -302.92  0  302.92  0  0  0  0  3000  0
0  302.92  0  20.8  0  33.96  0  0  0  0
0  0  0  33.96  0  19.04  0  33.96  0  0
0  0  0  0  0  33.96  50  5.11  0  0
```

REAL	IMAGINARY	MAGNITUDE	ANGLE
0.61960	0.00354	0.61961	0.32768
0.59526	-5.64561	5.67690	-83.98114
-5.89132	3.42624	6.81519	149.81880
2.70776	3.72465	4.60489	53.98348

fig. 9. Sample of the Gauss-Jordan program output. The numerical is the input matrix which contains all the coefficients, while the listing below represents the currents I_1 through I_4 in cartesian ($I_m \pm jI_m$) and polar coordinates ($I/0$).

can be used as they stand, included as subroutines that can be used as is, or be included as subroutines in a larger program. The solution in the figure is for I_{C4}.

conclusion

While the bulk of this work was done on a Tandy™ 2000 and the programs are written in MS-DOS BASIC, even the large matrix-handling program

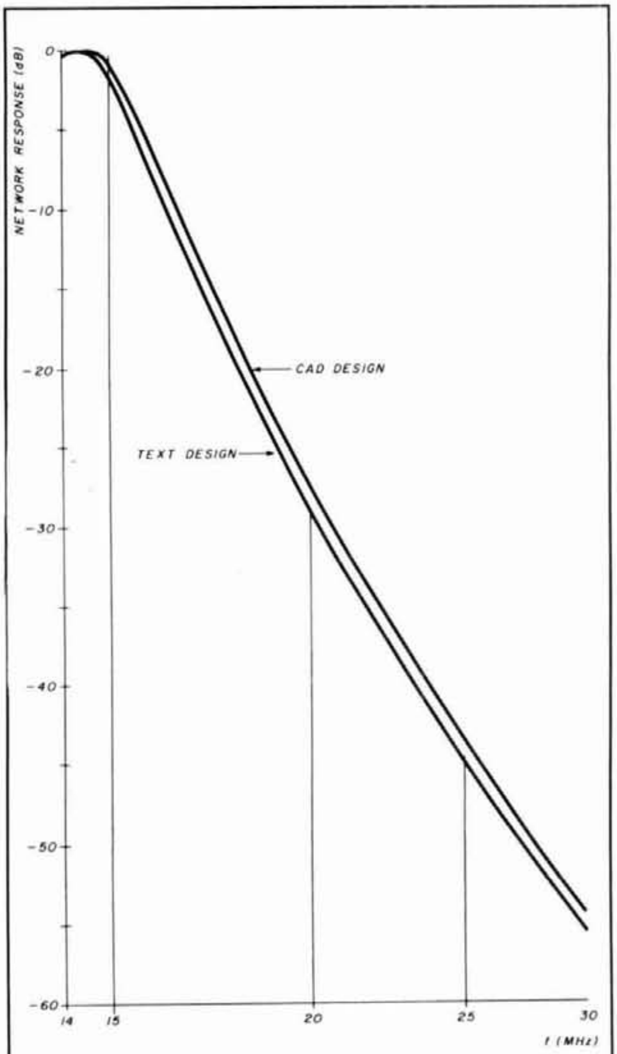

fig. 10. Calculated total network responses from 14.0 to 30.0 MHz. Both the text-designed and the CAD designed network responses are plotted.

represented by the Gauss-Jordan routine can be performed on the Commodore 64™ if the formatting lines (PRINT USING) and the integer symbols (%) are removed. It takes 30 to 45 seconds for the first solution to a four-current problem to appear on the C-64; the T-2000 requires only 6 seconds. With a compiled program the answers seem to appear instantaneously.

A few pertinent comments about using the Gauss-Jordan routine in this context are in order. The program will handle up to eight equations, but four seem to be the maximum number of equations one would want to try to solve. The execution time increases as approximately the cube of the number of equations, and there's a continuous rounding-off of the answers. While double-precision might help, the C-64 doesn't offer it, and I'd prefer to have this article remain useful to owners of the Commodore machines.

```
10 PRINT"                          COMPLEX ARITHMETIC:"
20 PRINT"                   ADD, SUBTRACT, MULTIPLY OR DIVIDE"
30 PRINT"                          TWO COMPLEX NUMBERS"
40 PRINT:
50 INPUT "ENTER REAL PART, FIRST NUMBER";RL1
60 INPUT "ENTER IMAGINARY PART, FIRST NUMBER";IM1
70 INPUT "ENTER REAL PART, SECOND NUMBER";RL2
80 INPUT "ENTER IMAGINARY PART, SECOND NUMBER";IM2:PRINT:
90 SIGN$= "-"
100 INPUT"ADD (1), SUBTRACT (2), MULTIPLY (3), OR DIVIDE (4)";Q:
110 ON Q GOTO 200, 300, 400, 600
120 GOTO 100
200 RL = RL1+RL2:IM=IM1+IM2:GOTO 630
300 RL=RL1-RL2:IM=IM1-IM2:GOTO 630
400 RL=RL1*RL2-(IM1*IM2):IM=IM1*RL2+RL1*IM2:GOTO 630
600 RL=(RL1*RL2+IM1*IM2)/(RL2^2+IM2^2)
610 IM=(IM1*RL2-RL1*IM2)/(RL2^2+IM2^2)
630 IF ABS(IM) = IM THEN SIGN$="+"
640 PRINT:PRINT"THE ANSWER IS    (";RL;" ";SIGN$;" J";ABS(IM)")"
650 PRINT:INPUT"ANY MORE? Y OR N";B$:PRINT
660 IF B$="Y" THEN 50: ELSE 670
670 END


RUN
                     COMPLEX ARITHMETIC:
              ADD, SUBTRACT, MULTIPLY OR DIVIDE
                     TWO COMPLEX NUMBERS

ENTER REAL PART, FIRST NUMBER? -7.327
ENTER IMAGINARY PART, FIRST NUMBER? 2.835
ENTER REAL PART, SECOND NUMBER? 2.356
ENTER IMAGINARY PART, SECOND NUMBER? 4.844

ADD (1), SUBTRACT (2), MULTIPLY (3), OR DIVIDE (4)? 2

THE ANSWER IS    (-9.683001  - J 2.009 )

ANY MORE? Y OR N? N
```

fig. 11. BASIC "four-factor" routines for the manipulation of two complex numbers. Useful as it stands, it is also useful for inclusion as steps in larger programs. The solution is for IC_4.

This article has defined a design problem, outlined the steps used to solve it with a PC, and produced a viable design that could probably be built with reasonable assurance that the final product would work. What began with an innocent question — "How is a no-tune amplifier designed?" — has ended with an amplifier actually under construction. Every design number and every program necessary to duplicate or extend that design have been presented here.

acknowledgments

I wish to thank Forrest Gehrke, K2BT, and Frank Chess, K3BN, for their useful suggestions and for their help in organizing this article.

references

1. *The Radio Amateur's Handbook*, American Radio Relay League, 54th edition, 19XX, page 54. (Note: the erroneous equation in the handbook has been corrected in this article.)

2. *The Radio Amateur's Handbook*, American Radio Relay League, 61st edition, 1984. Filter No. 8, Table 12, page 2-42.

3. *RF-CAD Electronics Design Program*, Joe Reisert, W1JR, and Gary Field, WA1GRC. Available from Ham Radio's Bookstore, Greenville, New Hampshire 03048, for $39.95 plus $3.50 shipping and handling.

4. *Basic Programs for Scientists and Engineers*, Alan R. Miller, SYBEX, 2021 Challenger Drive No. 100, Alameda, California 94501.

ham radio

lightning location and detection

Modern analog, digital techniques probe Nature's electrical generator

Lightning is an everyday occurrence, feared by some, accepted by most, but generally overlooked. Some 2000 thunderstorms are active at any moment throughout the world; this results in 100 lightning strokes every second of the year, or 40 million strokes per year in the United States alone.

Accurate detection of lightning is necessary for many reasons, including forest fire detection and control, power grid monitoring, flight planning, and public safety; NASA monitors lightning activity at various missile launch sites. Fortunately, technology now provides the means to accomplish these tasks with a high degree of accuracy.

North America has several extensive detection systems. Mexico, South Africa, Japan, Australia, Norway, Sweden, and recently China, have installed similar systems.

theory of detection

A lightning discharge to ground contains several large current surges or strokes. A *stepped leader* proceeds from the cloud to the ground in a series of short steps. After this leader reaches ground, a large return stroke travels rapidly back up the ionized path left by the leader. After a pause of 30 to 50 milliseconds, a *dart leader* usually forms; this is followed by one or more return strokes traveling upwards. Typically, a lightning stroke contains three, four, or more return strokes.

Until recently it was thought that a negative charge was transferred to ground during a lightning strike. But we now know that the incidence of positive charges increases as latitude increases towards the Earth's poles. Japanese researchers have also detected a large amount of positive lightning, which appears to emanate from the tops of clouds and be of higher current levels than negative lightning. There's still a considerable amount of research to be done in this area.

The current in return strokes attains levels of up to 40 kiloamps in 1 to 10 microseconds. The rise time and pulse width of this discharge form a distinctive waveform or signature that can be processed by the detection equipment to yield such data as azimuth bearings, real time, amplitude, polarity, and repetition of return strokes. When the data from two or more sites are triangulated and decoded by a central microprocessor, it's possible to pinpoint strike locations accurately to within 0.5 km at distances of 500 km.

detection system components

A typical detection system consists of two or more direction finders and a microcomputer; a block diagram of such a system is shown in **fig. 1**. Data is usually transmitted to a central *position analyzer* (PA) by means of dedicated telephone lines. Some installations use a polling system in which each direction finding site is polled. These systems require the use of asynchronous telephone lines. Recently, sites in remote areas (see **fig. 2**), especially in Third World countries, have used data transfer systems consisting of VHF and UHF radio links, using the principles of packet radio.

The electromagnetic field generated by a lightning stroke is sensed on two broadband orthogonal loop antennas and on an electric field, or "E" field, antenna. The latter consists of three flat plates stacked one above the other and separated by a few inches. The E field antenna senses the ambient noise level at a particular site to provide a comparison level for the loop antenna. The bandwidth of the antennas is 1 kHz to 1 MHz; this wide bandwidth is necessary to preserve the shape and polarity of the waveforms resulting from the lightning stroke.

Direction finding is done according to conventional techniques. The signal received by each loop is proportional to the lightning stroke's magnetic field multiplied by the cosine of the angle between the plane of the loop and the direction of the incoming signal.

By Bill Richardson, VY1CW, Site 20, Comp. 63, RR No. 1, Whitehorse, Yukon, Canada, Y1A 4Z6

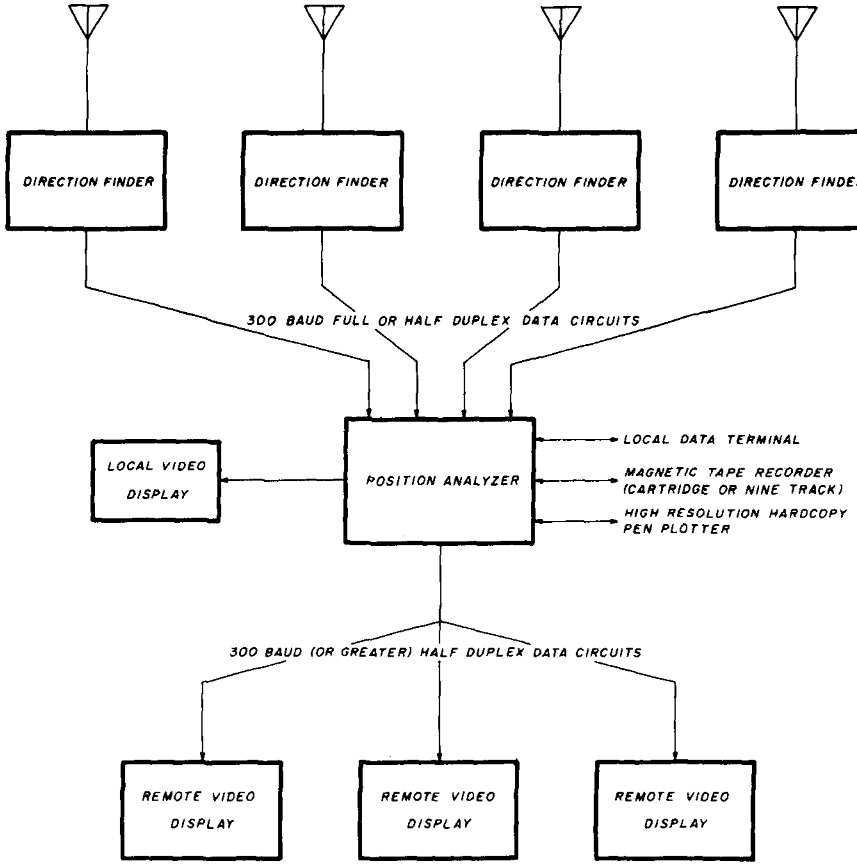

fig. 1. Block diagram of the basic LLP lightning locating system. In this example the position analyzer drives three remote display processors (RDP 80-02). In reality, the position analyzer may drive any number of remote display processors.

Therefore, the azimuthal bearing can be calculated from the signal strength ratio of the signals at the two loops.

The direction finding electronics are designed to respond to a waveform that's typical of a cloud-to-ground lightning stroke. Cloud-to-cloud lightning has an entirely different waveform and thus is ignored by the equipment.

These waveforms are identified by rise time, pulse width, and secondary peak structure. The rise time and bipolar shape requirements eliminate very distant lightning, because propagation delay increases the rise time of those waveforms. Ionospheric reflections of the signal don't pose a problem because they're typically inverted with respect to a ground wave signal. Some users employ both positive and negative stroke sensing.

The direction finder uses parallel low- and high-gain analog circuits. The waveshapes of near and distant lightning strokes are slightly different; therefore, the two analog circuits are set to switch automatically to values appropriate for subsequent strokes after the first stroke is detected. This provides maximum detection efficiency over a wide dynamic range.

Magnetic direction is determined at the time at which the radiation field of the return stroke reaches its peak; this point is attained while the return stroke is within approximately 300 feet of the ground. This provides an accurate indication of the ground contact point and eliminates errors that could be induced by multiple branch currents.

Detection efficiency is shown in **fig. 3**. The low efficiency at very close distances is caused by signals of sufficient magnitude to overrange the electronics. Peak efficiency is reached in the 20- to 250-km range and decreases beyond this because of lowering of signal amplitude and change of waveshape because of propagation delay.

As previously mentioned, accuracy can be within 0.5 to 1 kilometer at 300 kilometers, assuming enough direction finding sites are used for full area coverage. The electronics must be precisely aligned and calibrated — a very tedious procedure, I assure you. Alignment of the loop antennas must also be done

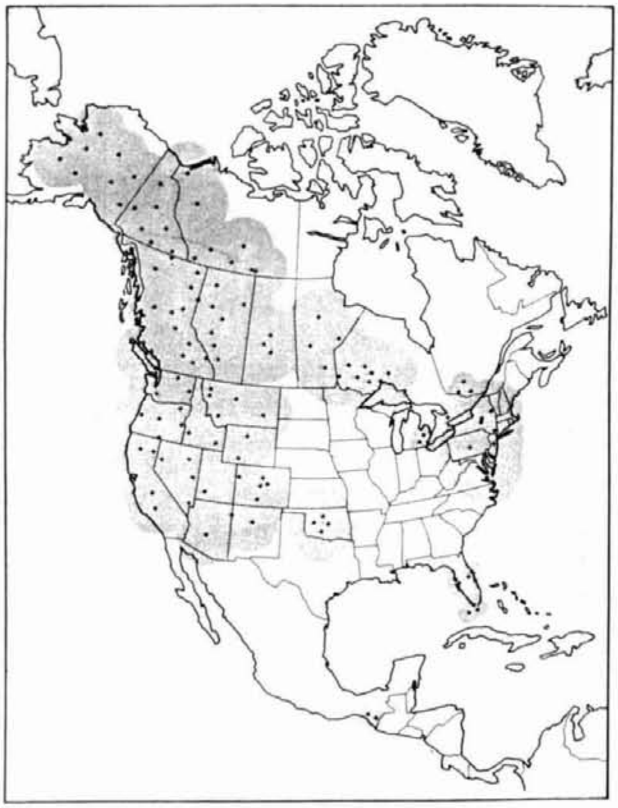

fig. 2. The solid dots show the locations of all LLP lightning direction finders installed in North America at the end of 1982. The shaded area represents the effective area covered by these systems.

accurately. The presently accepted method uses a shadow cast upon the antenna base plate by the north-south loop at precisely solar noon. Each direction finder has a built-in lightning simulator that can be set to duplicate acceptable and unacceptable lightning waveforms; this allows the system to be configured for peak detection efficiency.

system configuration

Sometimes a direction finder is used in a stand-alone mode, usually in conjunction with a weather radar. In this case, lightning data is plotted on an X-Y recorder. Clusters of vectors show the bearing to a storm cell; since vector length is proportional to the peak amplitude of the first return stroke, the length of the vectors can be translated into the distance to the strike.

The most common system configuration involves several direction finders reporting to a central position analyzer. Each direction finder has an integral microcomputer subsystem that digitizes and stores data for up to 14 return strokes. Each stroke is displayed on a front panel LED display. Time, angle to stroke, signal amplitude, polarity, and multiplicity of strokes are shown. This data is then transmitted to the position analyzer, a preprogrammed microcomputer system that automatically computes, maps, and records all lightning data. This data is then printed as hard copy and displayed on a CRT as lightning strikes superimposed on a map.

All computations and displays are done in real time. Data can be stored and replayed to determine storm

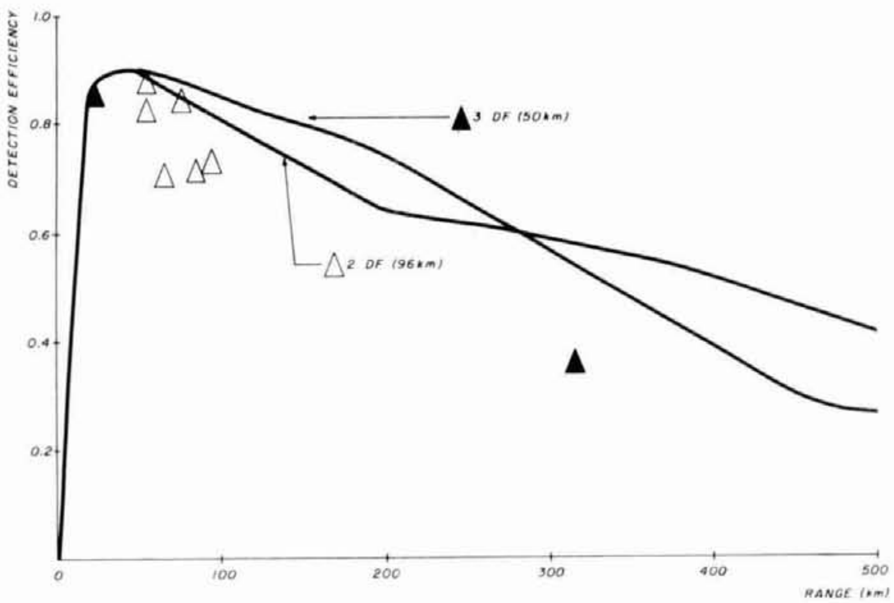

fig. 3. Detection efficiency versus range for two medium-gain LLP networks.

direction, intensity, growth, and decay. For example, a program can be selected to periodically delete strike locations older than a preset time interval, with various colors assigned to strikes occurring within different time periods. This accumulated data can then be replayed at an accelerated rate to display the storm's life cycle.

communications system

Time has shown that the communications links are the greatest source of problems in the system. Two basic systems — the "star" and the polled — are in common use. The polled system stores data until the PA requests it. In the star system, the simpler of the two, remote sites are connected to the PA via dedicated half-duplex telephone lines, and data is transmitted to the PA in real time. Though costs are higher with this system because of the dedicated line, which is in constant use, the system's simplicity often compensates for its higher costs.

In the past two years, many Third World countries have installed lightning detection equipment. Because standard communications links are almost non-existent in many of these areas, UHF radio links using packet radio have been used; to date, the results are very encouraging. Many such UHF links will be installed in northern and otherwise remote areas of North America over the coming year. This will not only allow new areas to be covered, but also decrease communications costs.

The manufacturer of the equipment described in this article has introduced a simplified direction finder which can be operated on solar power. This feature will help increases coverage, since ac power sources will no longer be required.

I'll be working closely with the manufacturer to experiment with the possibility of relaying data by radio transmissions reflected from the ionized trails created by the lightning stroke, much like the method used in meteor scatter communications.

conclusion

Space limits the depth of description of lightning detection equipment and techniques, but the foregoing should provide a general overview of this new technology. Because the field is still in its infancy, systems are especially challenging. Much research and development can and is being done by field personnel.

acknowledgements

My thanks to Leon Byerly of Lightning Location and Protection, 1001 South Euclid Avenue, Tuscon, Arizona 85719, for his help in preparation of this article.

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16	ST-16	.14	WW-16	.68	HR-14	.88
18	ST-18	.16	WW-18	.98	HR-18	1.04
20	ST-20	.18	WW-20	1.04	HR-20	1.24
22	ST-22	.20	WW-22	1.34	HR-22	1.34
24	ST-24	.20	WW-24	1.44	HR-24	1.44
28	ST-28	.22	WW-28	1.84	HR-28	1.94
40	ST-40	.25	WW-40	1.94	HR-40	2.34

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2101	1.49	2016-15	1.29
2102	.79	2016-10	1.69
2102L-4	.99	6116-4	1.29
2102L-2	1.29	6116-3	1.39
2111	2.29	6116-2	1.89
2112	1.89	6116LP-4	1.29
2114	.89	6116LP-3	1.39
2114-25	.99	6116LP-2	2.49
2114L-4	.89	Z-6132	29.89
2114L-3	1.09	6264P-15	3.29
2114L-2	1.29	6264P-12	3.49
21C14	.49	6264P-10	3.29
2147	2.89	6264LP-15	3.39
MK4118	6.89	6264LP-12	7.69
5101	1.89	6264LP-10	8.89
TMS4044-4	1.49	62256P-12	24.60
TMS4044-3	1.69	62256LP-12	26.89
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MK4108	.49	41256-20	2.69
MM5298	.49	41256-15	2.89
2118	2.89	41256-12	3.49
4116-20	.49	41256-10	6.69
4116-15	.69	4416-15	3.69
4116-12	1.29	4464-15	4.89

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1702	3.89	2732A-4	3.09
2708	2.89	2764	2.89
2758	2.89	2764-30	3.49
2716	2.49	2764-25	3.59
2716-5	1.89	2764-20	3.89
2716-1	3.49	2764A	4.89
TMS2516	3.69	27128	3.69
TMS2564	2.89	27128-45	3.49
TMS2532	4.89	27128-3	3.69
TMS2716	5.89	27128-25	3.89
2732	2.89	27128-2	4.39
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MCM68766	16.89	27256-25	6.89
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7815T	.48	7912T	.48
7824T	.48	7915T	.48
7805K	1.18	7924T	.48
7812K	1.18	7905K	1.18
7815K	1.18	7912K	1.18
7824K	1.18	7915K	1.18
78L05	.48	7924K	1.18
78L12	.48	79L05	.58
78L15	.48	79L12	.58
78H05K	6.88	79L15	.78

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PART#	FREQ	PRICE
1.000	1.0000MHz	3.00
1.843	1.8432MHz	3.00
2.000	2.0000MHz	3.00
4.000	4.0000MHz	3.00
6.000	6.0000MHz	3.00
10.000	10.0000MHz	3.00
16.000	16.0000MHz	3.00
18.432	18.4320MHz	3.00
19.000	19.0000MHz	3.00
20.000	20.0000MHz	3.00
32.000	32.0000MHz	3.00

7400

7400	.18	74143	2.80
7401	.18	74145	.58
7402	.18	74147	1.75
7403	.18	74148	1.75
7404	.18	74150	1.30
7405	.24	74151	.54
7406	.28	74152	.64
7407	.28	74153	.54
7408	.23	74154	1.20
7409	.18	74155	.74
7410	.18	74156	.64
7411	.24	74157	.54
7412	.28	74159	1.60
7413	.34	74160	.84
7414	.48	74161	.68
7416	.24	74162	.84
7417	.24	74163	.68
7420	.18	74164	.84
7421	.34	74165	.84
7422	.34	74166	.85
7423	.28	74167	2.90
7425	.28	74171	1.60
7426	.28	74172	5.90
7427	.28	74173	.74
7428	.44	74174	.68
7430	.18	74175	.68
7432	.28	74176	.88
7433	.44	74177	.74
7437	.28	74178	1.10
7438	.28	74179	1.70
7440	.18	74180	.74
7442	.48	74181	2.20
7443	.64	74182	.74
7444	.66	74184	1.85
7445	.68	74185	1.85
7446	.68	74186	1.95
7447	.68	74190	1.10
7448	.68	74191	1.10
7450	.18	74192	.78
7451	.22	74193	.78
7453	.22	74194	.84
7454	.22	74195	.84
7460	.22	74196	.78
7470	.34	74197	.74
7472	.28	74198	1.34
7473	.33	74199	1.34
7474	.32	74221	1.34
7475	.44	74246	1.34
7476	.34	74247	1.24
7480	.58	74248	1.60
7481	1.06	74249	1.60
7482	.84	74251	.74
7483	.48	74259	2.20
7485	.58	74265	1.30
7486	.34	74273	1.60
7489	2.10	74276	1.20
7490	.34	74278	2.90
7491	.38	74279	.74
7492	.48	74283	1.95
7493	.34	74284	3.70
7494	.64	74285	3.70
7495	.64	74290	.84
7496	.69	74293	.74
7497	2.70	74298	.84
74100	1.70	74351	2.20
74104	1.70	74365	.64
74107	.28	74366	.64
74109	.44	74367	.64
74110	.44	74368	.64
74111	.54	74376	2.18
74116	1.58	74390	1.70
74120	1.18	74393	1.30
74121	.28	74425	3.10
74122	.44	74490	2.60
74123	.48		
74125	.44		
74126	1.44		
74128	.54		
74132	.44		
74136	.40		
74141	.64		
74142	2.00		

CRYSTALS

1.0000 MHz	2.00	6.5536 MHz	1.00
1.8432 MHz	2.00	8.0000 MHz	1.00
2.0000 MHz	1.00	10.0000 MHz	1.00
2.0972 MHz	1.00	10.7386 MHz	1.00
2.4576 MHz	1.00	12.0000 MHz	1.00
3.2768 MHz	1.00	14.3182 MHz	1.00
3.5795 MHz	1.00	15.0000 MHz	1.00
4.0000 MHz	1.00	16.0000 MHz	1.00
4.1943 MHz	1.00	17.4300 MHz	1.00
5.0000 MHz	1.00	18.0000 MHz	1.00
5.0688 MHz	1.00	18.4320 MHz	1.00
5.1850 MHz	1.00	19.6608 MHz	1.00
5.2420 MHz	1.00	20.0000 MHz	1.00
5.7143 MHz	1.00	22.1184 MHz	1.00
6.0000 MHz	1.00	32.0000 MHz	1.00
6.1440 MHz	1.00	36.0000 MHz	1.00
6.4000 MHz	1.00	40.0000 MHz	1.00

74LS00

74LS00	.14	74LS160	3.88
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74LS02	.14	74LS191	.48
74LS03	.14	74LS192	.88
74LS04	.14	74LS193	.68
74LS05	.16	74LS194	.58
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74LS09	.16	74LS196	.58
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74LS15	.24	74LS243	.68
74LS20	.18	74LS244	.58
74LS21	.20	74LS245	.68
74LS22	.28	74LS247	.68
74LS26	.20	74LS248	.68
74LS27	.20	74LS249	.98
74LS28	.24	74LS251	.48
74LS30	.18	74LS253	.48
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74LS33	.28	74LS258	.48
74LS37	.24	74LS259	1.18
74LS38	.24	74LS260	.48
74LS40	.18	74LS266	.38
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74LS49	.68	74LS280	1.18
74LS51	.18	74LS283	.58
74LS54	.18	74LS290	.68
74LS55	.20	74LS295	.68
74LS63	.68	74LS298	.68
74LS73	.28	74LS299	1.48
74LS74	.22	74LS323	2.48
74LS75	.28	74LS324	1.88
74LS76	.28	74LS326	3.49
74LS78	.38	74LS352	1.24
74LS83	.48	74LS353	1.18
74LS85	.48	74LS363	1.28
74LS86	.20	74LS364	1.98
74LS90	.38	74LS365	.38
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74LS92	.48	74LS367	.38
74LS93	.38	74LS368	.38
74LS95	.48	74LS373	.78
74LS96	.48	74LS374	.78
74LS107	.32	74LS375	.78
74LS109	.34	74LS377	.78
74LS112	.28	74LS378	1.12
74LS113	.32	74LS379	.88
74LS114	.32	74LS385	1.84
74LS122	.44	74LS386	.42
74LS123	.48	74LS390	1.08
74LS124	2.60	74LS393	.78
74LS125	.38	74LS395	1.08
74LS126	.38	74LS399	1.08
74LS132	.38	74LS424	2.88
74LS133	.48	74LS445	2.88
74LS136	.38	74LS447	.92
74LS137	.88	74LS461	1.48
74LS138	.38	74LS490	1.48
74LS139	.38	74LS624	1.92
74LS145	.88	74LS640	.98
74LS147	.88	74LS641	.98
74LS148	.88	74LS645	.98
74LS151	.38	74LS648	.98
74LS153	.38	74LS668	1.48
74LS154	1.48	74LS669	1.28
74LS155	.48	74LS670	.88
74LS156	.48	74LS674	8.58
74LS157	.34	74LS682	3.14
74LS158	.28	74LS683	2.88
74LS160	.38	74LS684	2.88
74LS161	.38	74LS686	2.88
74LS162	.48	74LS688	1.88
74LS163	.38	74LS689	2.88
74LS164	.48	74LS783	21.98
74LS165	.64	26LS30	1.78
74LS166	.68	26LS31	1.78
74LS168	.84	26LS32	1.78
74LS169	.84	26LS33	1.78
74LS170	.64	81LS95	1.38
74LS173	.48	81LS96	1.38
74LS174	.38	81LS97	1.38
74LS175	.38	81LS98	1.38
74LS181	1.48	25LS2521	2.48
		25LS2569	2.48

6500

6502	1.99	6551	5.89
6504	6.79	6502A	2.49
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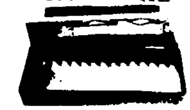

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designing a microwave amplifier

Step-by-step procedure starts with specs, ends with results

Most people who aren't familiar with microwave technology regard microwave engineering as somewhat mysterious. Nothing could be further from the truth.

Often this opinion stems simply from limited knowledge of the subject, from a misconception that all power transmission requires a waveguide or "plumbing," or from a general lack of interest. Knowing that in microwave design, circuit performance is exceptionally dependent on layout* and understanding the mathematics associated with field theory and the use of distributed parameters for impedance matching, it's possible to conclude that microwave engineering is an arcane art limited to the very few. *Not so!*

S-parameters

Manufacturers of microwave electronic components, namely transistors, characterize these devices according to scattering parameters known also as "S" parameters. S parameters are simply voltage reflection coefficients that possess both magnitude and phase. Consider a 25-ohm resistor at the end of a 50-ohm transmission line (**fig. 1**). The reflection coefficient of the 25-ohm load is computed as follows:

$$\Gamma = \frac{Z_L - Z0}{Z_L + Z0} = \frac{25 - 50}{25 + 50} = \frac{-25}{75} = \frac{-1}{3} \quad (1)$$

Γ can be complex and is simply a reflection coefficient; that's what an S parameter is — nothing more than a reflection coefficient. The S parameters are measured values and give an indication as to the performance of the device, and are generally measured in a 50-ohm system. It's more practical to construct a 50-ohm termination than to rely upon open circuits and short circuits and attempt to characterize a device with "Y" or "Z" parameters. The four S parameters specified are S11, S12, S21, and S22 (see **fig. 2**).

$$S11 = \frac{b1}{a1} \text{ with } a2 = 0 \text{ and} \quad (2)$$

is a measure of input impedance

$$S22 = \frac{b2}{a2} \text{ with } a1 = 0 \text{ and}$$

is a measure of output impedance

$$S21 = \frac{b2}{a1} \text{ with } a2 = 0 \text{ and is a measure of forward power gain}$$

$$S12 = \frac{b1}{a2} \text{ with } a1 = 0 \text{ and}$$

is a measure of reverse power gain

S parameters are simply related to power gain and mismatch loss, quantities which are often of more interest than the corresponding voltage functions.

$$|S11|^2 = \frac{\text{Power reflected from network input}}{\text{Power incident on the network input}}$$

$$|S22|^2 = \frac{\text{Power reflected from network output}}{\text{Power incident on the network output}}$$

$$|S21|^2 = \frac{\text{Power delivered to a Z0 load}}{\text{Power available from Z0 source}}$$

$$|S12|^2 = \frac{\text{Reverse transducer power gain}}{\text{with Z0 load and source}}$$

It's important to understand that S parameters are measured parameters and give the designer a real-world indication as to how the particular transistor will work. Generally, a designer's most important considerations are power gain, noise figure, stability, biasing, and a necessary matching structure for reasonable VSWR.

A transistor is a bilateral device, with the amount of bilateral interaction defined by S12. Analyzing the performance of an amplifier operating as a bilateral device is a tedious process, and one has to resort to the use of computers and commercially available programs

*i.e., you don't wire a 4-GHz amplifier the same way you'd wire a car. Consider that a piece of No. 26 wire measuring 0.050 inches long represents an impedance of j25 ohms at 4.0 GHz. This would introduce a voltage SWR (mismatch) of 1.63:1, with 5.8 percent of the power reflected back to the generator should this wire be connected in series in a 50-ohm system.

By Stanley J. Domanski, ex-WA1WSD, 3 Lessard Street, Nashua, New Hampshire 03060

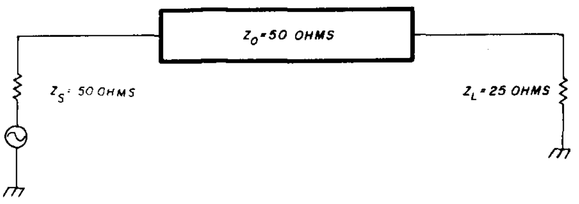

fig. 1. Mismatch occurs when 25-ohm load is inserted directly in 50-ohm system.

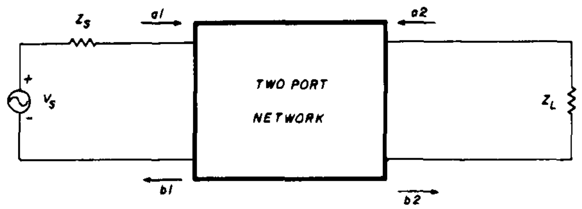

fig. 2. Two-port network used to define S parameters.

such as Super-Compact,** a rather powerful microwave circuit design optimization program. For the purpose of illustration, we will assume a unilateral device (S12 = 0.0).

using the data sheet

Suppose someone gives you several NEC NE388 GaAsFET transistors and a data sheet, then asks you to design an amplifier that's to operate at 3 GHz. Approximately how much gain should you expect to achieve? What would the input and output matching network look like?

Start by reviewing the data sheet for the FETs. (For this design, noise figure is not a consideration.) The load impedance and source impedance are both 50 ohms. The device is a GaAsFET. You'll also notice that the S parameters are specified at V_{DS} = 3.0 volts and I_D = 10 mA. Therefore, for the matching network to be effective and for the gain calibration to be meaningful, the device must be biased at these values of V_{DS} and I_D. Try to get a feeling for maximum usable gain, i.e. the Gain Transducer Unilateral (GTU). (This assumes a unilateral device where S12 = 0 and a matched source and load condition exists.) This was derived from the more general equation for GT (Gain Transducer) under the conditions specified above.

$$GTU\ max = \frac{1}{1-|S11|^2} \bullet |S21|^2 \bullet \frac{1}{1-|S22|^2} \quad (3)$$

At 3000 MHz,

$$S11 = 0.892\ \underline{|-63^\circ},\ S21 = 2.368\ \underline{|133^\circ} \quad (4)$$

$$S22 = 0.772\ \underline{|-41^\circ},\ S12 = 0.034\ \underline{|52^\circ}$$

$$GTU = \frac{1}{1-(0.892)^2} \bullet \frac{(2.368)^2}{1} \bullet \quad (5)$$

$$\frac{1}{1-(0.772)^2} = (4.893) \bullet (5.607) \bullet (2.475) =$$

$$67.90 \text{ or } 10 \log GTU = 18.32 \text{ dB}$$

This computation is consistent with the data sheet. Notice that in addition to providing a table of S parameters for the packaged devices, S parameters are given for NE388 chips as well, and the S parameter data is listed for frequencies from 2 to 10 GHz in 0.5-GHz step increments. Note that S11 and S12 are both capacitive, but become more inductive as frequency increases.

S11 represents approximately 10 − j80 ohms and S22 represents approximately 50 − j120 ohms. For optimum performance and power gain, the transistor's input and output impedances should be matched to 50 ohms.

One suitable way of constructing this amplifier is a technique called *microstrip*. Microstrip possesses transmission line characteristics and is essentially just conductive runs over a conducting ground plane, with an intermediate substrate in between.

matching procedure

The idea is to "move" S22 and S11 to the 50-ohm center of the Smith Chart (**fig. 3**). In both cases, this is done by rotating on a length of transmission to the constant conductance circle that is coincident with the center of the Smith Chart or the 50-ohm location and then adding a parallel capacitor of the appropriate size. For the S22 match, a length of line 0.194λ + 0.055λ = 0.249λ is used to rotate to constant conductance circle coincident with 50 ohms; for S11 the length of line is:
0.163λ + 0.038λ = 0.201λ.
Y(S22) = 2.4 = Y/B0
Since our transmission line characteristic is Z0 and is 50 ohms,

B0 = 1/Z0 = 1/50 or 0.02
Y = y•B0 = 2.4 • 0.02 = 0.048 mhos
Y = 2πfC mhos

$$C = \frac{Y}{2\pi f} = \frac{0.048}{2\pi \times 3 \times 10^9} = 2.54 \times 10^{-12} \text{ farads}$$

A 2.54 • 10^{-12}F (2.54 pF) capacitor shunting the transmission line to ground will add enough susceptance to complete the output match to 50 ohms.

A similar procedure is used to match the input to 50 ohms.

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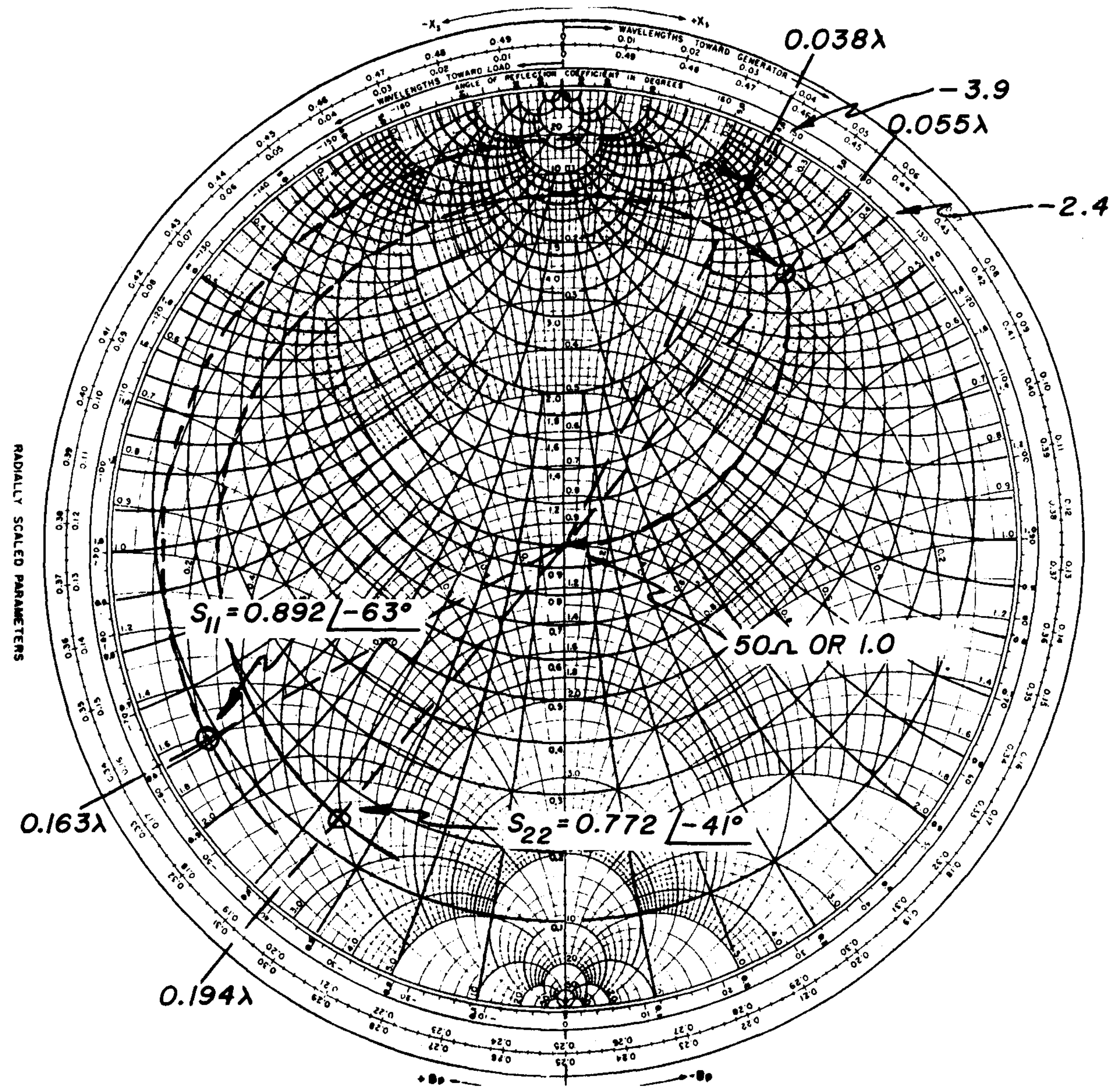

fig. 3. GaAsFET, NE388 matching using Smith Chart.

$$y(S11) = \frac{y}{BO} = 3.9 \text{ mhos}$$

$$Y = y \bullet BO \quad \textbf{(7)}$$

$$= 3.9 \times 0.02 = 0.078 \text{ mhos}$$

$$Y = 2\pi fc \text{ mhos} \quad C = \frac{Y}{2\pi f} = \frac{0.078}{2\pi \times 3 \times 10^9} \quad \textbf{(8)}$$

$$= 4.138 \times 10^{-12} \text{ Farad}$$

A 4.138 x 10^{-12}F (4.138 pF) capacitor shunting the transmission line to ground will add enough susceptance to complete the input match to 50 ohms. Thus far, what we have represented is shown schematically in **fig. 4**.

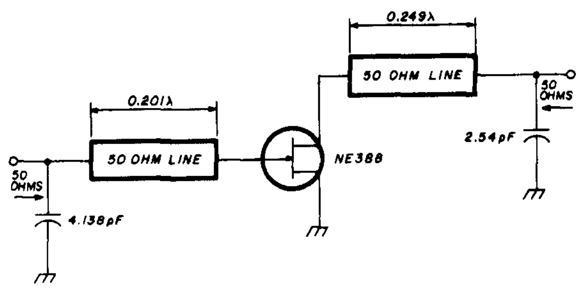

fig. 4. Component values determined for GaAsFET input/output match.

microstrip components used

The microstrip substrate is a teflon material with a dielectric constant of 10.0. The distributed characteristics of microstrip will be utilized to synthesize the 50-ohm transmission line and shunt capacitors. The lengths of the input and output transmission lines are 0.201λ, and 0.249λ, respectively.

The equation relating frequency and wavelength is $c = f\lambda$, where c is the velocity of light and is $3 \cdot 10^{10}$ cm/sec. In air, the wavelength of a 3-GHz signal is

$$\lambda = \frac{c}{f} = \frac{3 \times 10^{10}\ cm\ /\ sec}{3 \times 10^{9}\ Hz} = 10\ cm \qquad \textbf{(9)}$$

or approximately 3.937 inches. The effective wavelength in a material other than free space is the wavelength in free space divided by the square root of the dielectric constant. For a substrate whose dielectric constant is 10.0, the effective wavelength is

$$\frac{\lambda}{\sqrt{\epsilon_r}} = \frac{10.0\ cm}{\sqrt{10}} = 3.16\ cm \qquad \textbf{(10)}$$

or 1.2449 inches. The length of the input matching section is 0.201λ and the length of the output matching section is 0.249λ. This in air would represent (0.201λ) (3.937 inches/λ) = 0.7913 inches and (0.249λ) (3.937 inches/λ) = 0.9803 inches.

In a substrate with a dielectric constant of 10.0, the real lengths of the input and output become (0.7913 inches) (0.3162) = 0.2502 inches and (0.9803 inches) (0.3162) = 0.3099 inches, respectively.

The characteristic impedance of microstrip, Z0 is:

$$\frac{h}{w} \times 377 \times \frac{1}{\sqrt{\epsilon_r}} \qquad \textbf{(11)}$$

The impedance selected for our line is 50 ohms and ϵ_2 = 10.0. The substrate thickness is 0.020 inches. Solving for W:

$$\omega = \frac{377 \times h}{Z0 \times \sqrt{\epsilon_2}} = \frac{377 \times 0.020}{50 \times \sqrt{10}} = 0.0476\ in \qquad \textbf{(12)}$$

Thus the width of a conductor whose characteristic impedance is 50 ohms on a substrate whose thickness is 0.020 inches, with a dielectric constant of 10.0, is 0.0476 inches. The original schematic takes on a new aspect — dimensions (see **fig. 5**).

The input capacitance of 4.138 pF and output capacitance of 2.54 pF will be synthesized using microstrip techniques. Generally, if the width of a segment is twice as wide as the length, the section looks like a shunt capacitor.

The capacitance of a parallel plate capacitor is:

$$C\ (pF) = \frac{0.224\ A\ \epsilon_r}{d} \qquad \textbf{(13)}$$

where:

A is the area of the plate in square inches
d is the separation of the plates in inches
ϵ_r is the dielectric constant

Solving for A:

$$A1 = \frac{(C1)\ (d)}{(0.224)\ (\epsilon_r)} = \frac{(4.138)\ (0.020)}{(0.224)\ (10)} \qquad \textbf{(14)}$$
$$A1 = 0.0369\ in^2$$

Similarly:

$$A2 = \frac{(C2)\ (d)}{(0.224)\ (\epsilon_r)} = \frac{(2.54)\ (0.020)}{(0.224)\ (10)} \qquad \textbf{(15)}$$
$$= 0.0227 in^2$$

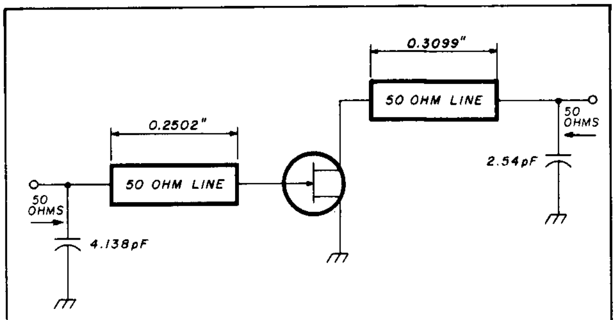

fig. 5. Transmission line physical parameters determined from requirements.

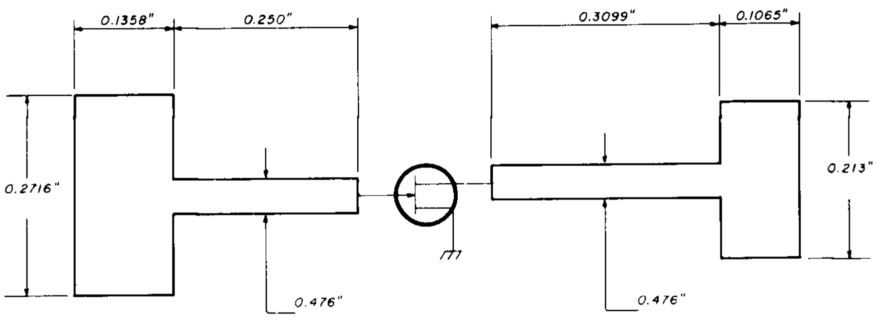

fig. 6. Input and output matching structure dimensions.

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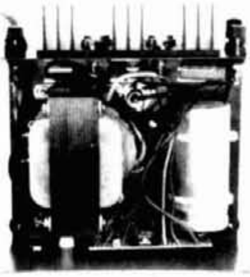

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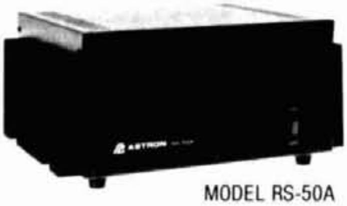

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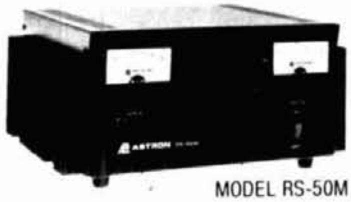

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RM-35A	25	35	5¼ × 19 × 12½	38
RM-50A	37	50	5¼ × 19 × 12½	50
• Separate Volt and Amp Meters				
RM-12M	9	12	5¼ × 19 × 8¼	16
RM-35M	25	35	5¼ × 19 × 12½	38
RM-50M	37	50	5¼ × 19 × 12½	50

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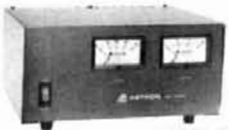
RS-4A	3	4	3¾ × 6½ × 9	5
RS-5A	4	5	3½ × 6⅛ × 7¼	7
RS-7A	5	7	3¾ × 6½ × 9	9
RS-7B	5	7	4 × 7½ × 10¾	10
RS-10A	7.5	10	4 × 7½ × 10¾	11
RS-12A	9	12	4½ × 8 × 9	13
RS-12B	9	12	4 × 7½ × 10¾	13
RS-20A	16	20	5 × 9 × 10½	18
RS-35A	25	35	5 × 11 × 11	27
RS-50A	37	50	6 × 13¾ × 11	46

RS-M SERIES



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MODEL	Continuous Duty (Amps)	ICS* (Amps)	Size (IN) H × W × D	Shipping Wt. (lbs.)
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• Separate volt and Amp meters				
RS-20M	16	20	5 × 9 × 10½	18
RS-35M	25	35	5 × 11 × 11	27
RS-50M	37	50	6 × 13¾ × 11	46

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VS-12M	9	5	2	12	4½ × 8 × 9	13
VS-20M	16	9	4	20	5 × 9 × 10½	20
VS-35M	25	15	7	35	5 × 11 × 11	29
VS-50M	37	22	10	50	6 × 13¾ × 11	46
• Variable rack mount power supplies						
VRM-35M	25	15	7	35	5¼ × 19 × 12½	38
VRM-50M	37	22	10	50	5¼ × 19 × 12½	50

RS-S SERIES

MODEL RS-12S

• Built in speaker

MODEL	Continuous Duty (Amps)	ICS* Amps	Size (IN) H × W × D	Shipping Wt. (lbs.)
RS-7S	5	7	4 × 7½ × 10¾	10
RS-10S	7.5	10	4 × 7½ × 10¾	12
RS-12S	9	12	4½ × 8 × 9	13
RS-20S	16	20	5 × 9 × 10½	18

*ICS—Intermittent Communication Service (50% Duty Cycle 5min. on 5 min. off)

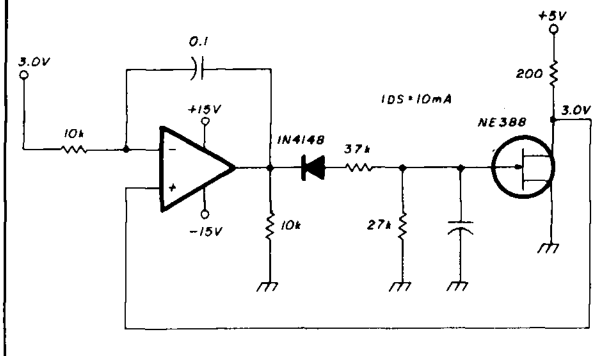

fig. 7. Feedback network improves amplifiers temperature-handling capability.

The circuit now takes on the appearance of that shown in **fig. 7.**

The basic radio frequency input and output matching structure is now defined.

This matching structure was based on S parameters which were stated for a given V_{DS} and I_{DS}. A GaAs-FET device is a transconductance device; this simply means that it's a voltage-controlled current source.

feedback and biasing

This brings up the means by which the devices should be biased. A quick glance at the data sheet reveals the NE388 will require a V_{GS} of approximately −3.0 volts to maintain a V_{DS} = 3.0 volts and I_{DS} = 10.0 milliamperes. But the V_{GS} necessary to maintain

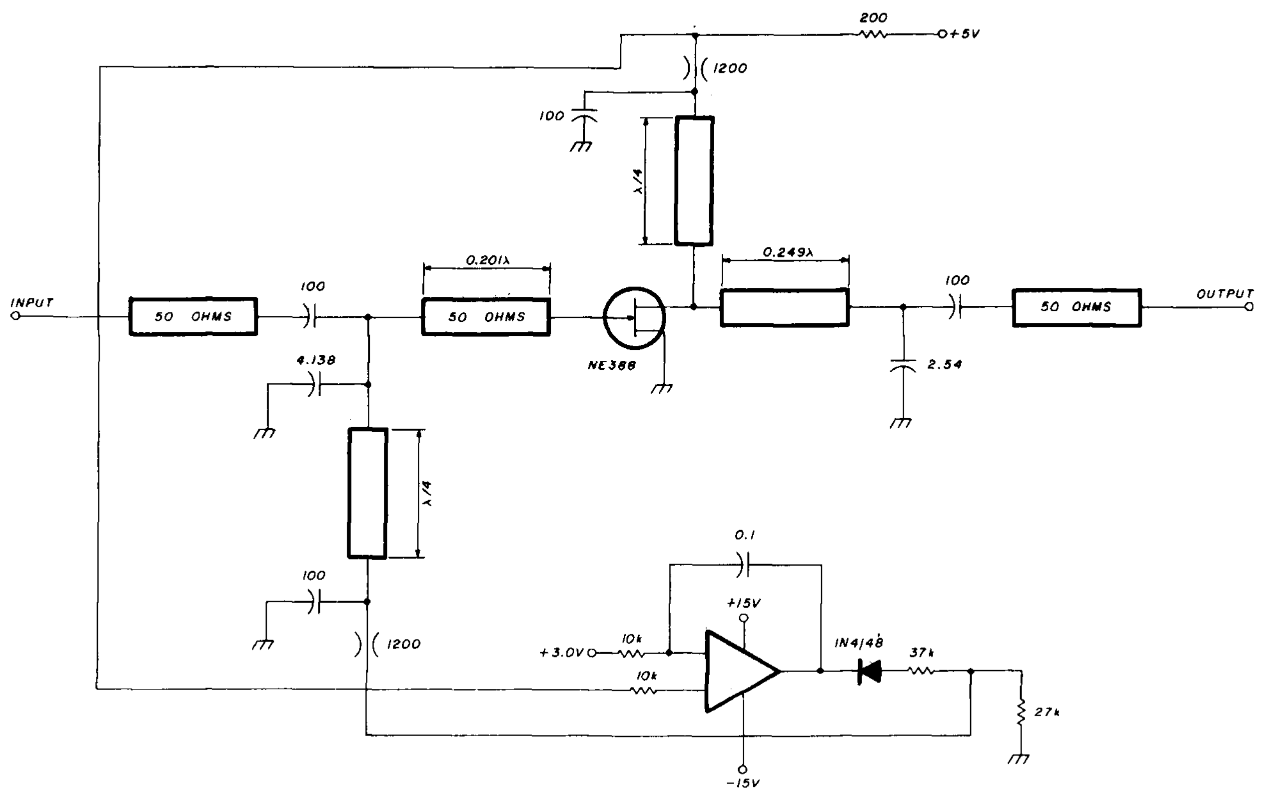

fig. 8. Complete distributed and lumped component 3GHz amplifier circuit.

We wish to make the width of the section twice as wide as the length. Therefore,

$$2\ell^2 = A1 \quad \ell^2 = \frac{A1}{2} \tag{16}$$

$$\ell = \sqrt{\frac{A1}{2}} = \sqrt{\frac{0.0369}{2}} = 0.1358 \ in$$

Similarly:

$$\ell^2 = \frac{A2}{2} \quad \ell = \tag{17}$$

$$\sqrt{\frac{A2}{2}} = \sqrt{\frac{0.0227}{2}} = 0.1065 \ in$$

these aforementioned bias conditions can vary between −2.5 to −3.5 volts — a production nightmare, especially if the unit must operate between −55 and +70 degrees C. Solution: use a servo — i.e., a feedback circuit!

I suggest the circuit shown in **fig. 8** because I know it works well over a wide range of temperatures. The microwave matching network components are left out for simplicity.

The three critical items in this circuit are the stability of the +5.0 volts, the accuracy and stability of the

200-ohm resistor, and the 3.0-volt reference. The diode prevents the possibility of a positive voltage being applied to the gate. A positive voltage on the gate without considerable current limiting would damage the device.

The voltage divider consisting of the 37.4-k and 27.4-k resistors prevent the gate to source voltage from exceeding −8.0 volts during initial turn-on. The dc bias, namely the V_{DS} and V_{GS} is applied to the NE388 through the use of high-impedance, quarter-wave, short-circuited stubs. The short circuit at 3 GHz is accomplished by wire-bonding the end of the stub to a 100-pF chip capacitor that is connected to ground. Remember, a quarter-wave long transmission line short-circuited on one end looks like an open circuit on the other. The design procedure results in the realizable 3-GHz amplifier circuit shown in **fig. 9**.

ham radio

simple VHF/UHF multiple quarter-wave filters

Individual or cascaded sections provide required harmonic suppression

Thanks to the simplicity of its design, construction, and alignment, the half-wave, low-pass configuration[1] is one of the most popular transmitter filters at VHF and UHF.

The half-wave filter, consisting of two pi sections of inductors and capacitors in cascade (see **fig. 1**), is so named because the output signal is delayed one-half wavelength* at the highest design pass frequency. Just as in the case of a half-wavelength transmission line, the same impedance seen at the output terminals of the half-wave filter is presented to the amplifier at the filter input terminals. The principal use of this filter is simply to reduce transmitter harmonics.

This article shows how to calculate the values for quarter, half, three-quarter, and full-wave VHF/UHF filters. The effects of varying the circuit *Q* will be explored. If reasonable construction techniques are used, a guaranteed minimum level of attenuation can be expected for transmitter harmonics, even without using test equipment for alignment. Multisection filters have been constructed using lumped constants for the 6, 2, and 1-1/4 meter bands, with very good agreement to theoretical values. Microstrip quarter-wave and half-wave filters have also been built for the 432- and 1296-MHz bands. Half-wave filters for the hf band can be constructed using standard values contained in tables[2,3] without need for adjustments. At VHF however, construction techniques dictate that the filter actually be adjusted for best performance, usually with a grid-dip meter. At UHF, construction practices require the use of a reproducible pattern found in microstripline form. If the same printed circuit board type and thickness are used, similar performance can be assured without any alignment.

*The signal is delayed 180 degrees or the equivalent that would occur in a properly terminated half-wave *electrical* transmission line. —Ed.

reducing interference

There are many reasons — legal, environmental, and ethical — for reducing spurious and harmonic emissions. According to Part 97.73 of the FCC Rules and Regulations for the Amateur, "Spurious emissions (including harmonics) must be 40 dB below the carrier power for a transmitter operating below 30 MHz. If the transmitter has an output power of 5 watts or less, the spurious at the transmitter output need only be reduced by 30 dB. Harmonics for transmitters and power amplifiers operating in the 30- to 235-MHz range must be reduced 60 dB below the carrier level. Transmitters below 25 watts output need to attenuate harmonics by only 40 dB."

With a typical amplifier, the second harmonic is only 20 to 30 dB down and the third harmonic is 30 to 40 dB down from the fundamental carrier (**fig. 2**). When the harmonic content of a transmitter, exciter, or oscillator is monitored on a spectrum analyzer or sensitive receiver, the carrier should be "notched-out" as much as possible. The input mixer of the spectrum analyzer or the front end of a receiver is prone to generate harmonic energy when driven by a large carrier signal, and will indicate greater harmonic energy than is actually present. The common method of determining if the amplitude of a transmitter harmonic is real is to place an attenuator in front of the spectrum analyzer. If the harmonic drops by an amount greater than the value of the inserted attenuation, then the harmonic was generated in the mixer of the analyzer.

In a balanced (i.e., push-pull) amplifier design, the second harmonic power will typically be down better than 30 dB (depending on circuit balance). The odd order (third, fifth) harmonics, however, will remain high (−20 dB). Thus the principal filtering response

By Ernie Franke, WA2EWT, 10484 138th Street, Largo, Florida 33544

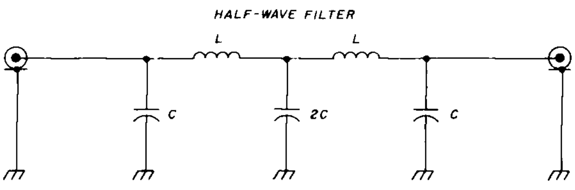

fig. 1 The half-wave filter is popular because of the simplicity of its calculation, construction, and adjustment.

$$X_L = 2\pi fL = 50 \text{ ohm}, \quad (1)$$
$$X_C = 1 / 2\pi fC = 50 \text{ ohm}$$

The value of inductance and capacitance is then simply computed as

$$L = 50 / 2\pi f \text{ henries}, \; C = 1 / 2\pi f (50) \text{ farads} \quad (2)$$

where f is the highest design pass frequency in Hz. The values of L and C may be directly scaled up or down, depending on the source and load impedances. The basic quarter-wave pi network may be considered

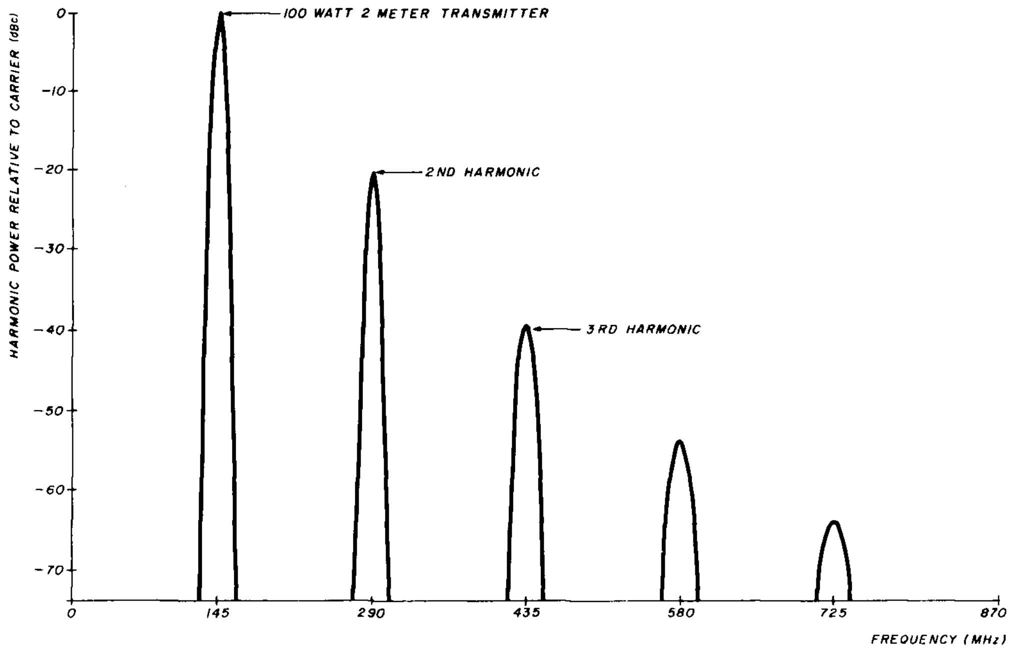

fig. 2. Typical power spectrum from a 2-meter, 100-watt transistor power amplifier.

required by a low-pass filter on a balanced amplifier will be out at the third harmonic.

design

The basic building block of the multiple quarter-wave filter is the quarter-wave pi network shown in **fig. 3**. Cascading of these quarter-wave networks forms the half-wave, three-quarter wave, and full-wave filters, providing the theoretical frequency responses shown in **fig. 4**. Experimental results for various section VHF filters are also shown. As each section is added, the slope of the stop-band becomes steeper. The responses of several filters constructed using lumped constants are shown to agree reasonably well with the theoretical values.

The inductive and capacitive reactances of the quarter-wave filter are chosen to be equal to the source and load impedances, typically 50 ohms.

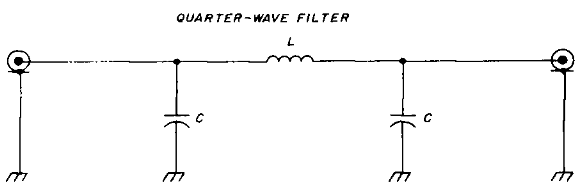

fig. 3. The quarter-wave filter, composed of two L-networks, represents the basic building block.

as two L-networks connected together, **fig. 5**. The Q of each L-network is given as

$$Q1 = R1 / X_{C1} = 2\pi f \, C1 \, R1 \text{ and} \quad (3)$$
$$Q2 = R2 / X_{C2} = 2\pi f \, C2 \, R2$$

The total circuit Q is equal[4] to the sum of the individual Q's:

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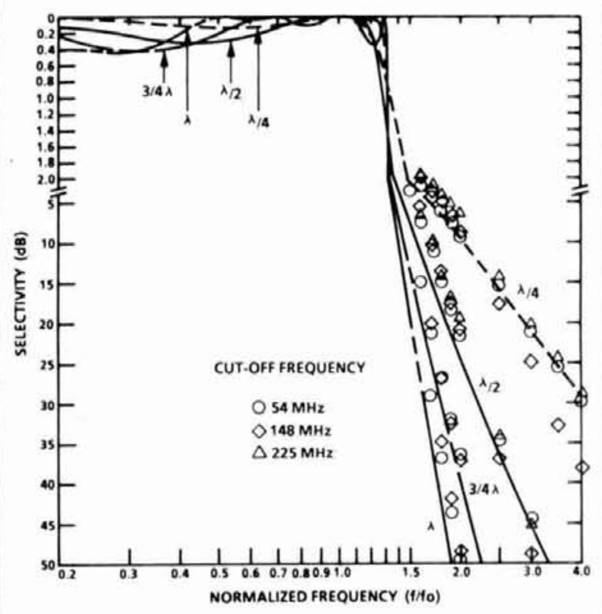


fig. 4. Frequency response of the quarter-, half-, three-quarter, and full-wave filters.

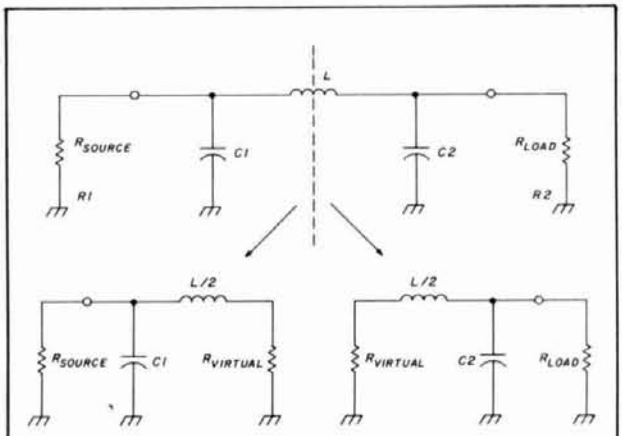


fig. 5. The basic building block may be split into two L matching networks.

$$Q_T = Q1 + Q2 \qquad \textbf{(4)}$$

and because of symmetry,

$$Q_T = 2Q1 \qquad \textbf{(5)}$$

The reactance, X_L, of the inductor and the reactance, X_c, of each capacitor is

$$X_L = R1Q_T / [(Q_T2 / 4) + 1] = 2R1Q1 / (Q1^2 + 1) = 2\pi fL; \quad L = R1Q1 / \pi f (Q1^2 + 1) \qquad \textbf{(6)}$$

$$X_c = R1 / Q1; C = Q1 / R1 \ 2\pi f \qquad \textbf{(7)}$$

For a 50-ohm source and load,

$$L = \frac{50Q1}{\pi f (Q1^2 + 1)} \text{ and } C = \frac{Q1}{50 (2\pi f)} \qquad \textbf{(8)}$$

In an L-network for a Q of 1, which yields an overall network Q_T of 2, the value of the inductance and each capacitance is

$$L = 50 (1) / \pi f (2) = 50 / 2\pi f, \qquad \textbf{(9)}$$

$$C = (1) / 50 (2\pi f) = 1 / 50 (2\pi f)$$

The filter for several values of overall Q_T have been calculated using the elements calculated according to

$$L = R1Q_T / [(Q_T^2 / 4) + 1](2\pi f) \qquad \textbf{(10)}$$

$$C = Q_T / R1 \ 4\pi f$$

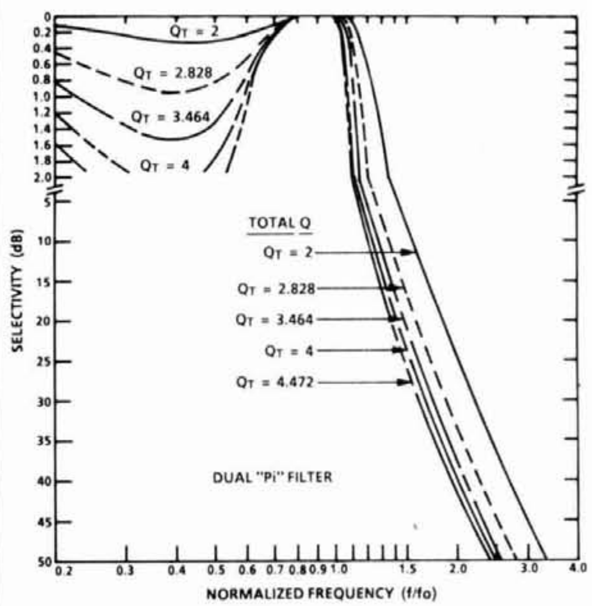


fig. 6. The overall loaded Q of the filter may be increased to yield greater harmonic attenuation — at the expense of greater in-band amplitude ripple.

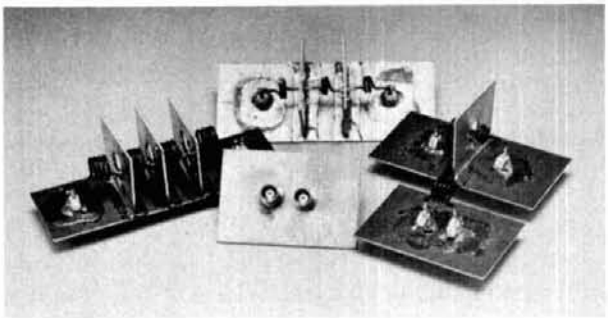


fig. 7. Several quarter-, half-, three-quarter, and full-wave filters were constructed using scrap PC boards.

Table 1. Basic quarter-wave filter elements.

shunt capacitor		series inductor			
frequency	value	value	wire size	number turns	diameter
54 MHz	59 pF	147 nH	No. 14	4T	3/8 inch ID
148 MHz	22 pF	54 nH	No. 14	2T	1/4 inch ID
25 MHz	14 pF	35 nH	No. 14	1 inch high, 1/2 inch wide hairpin	

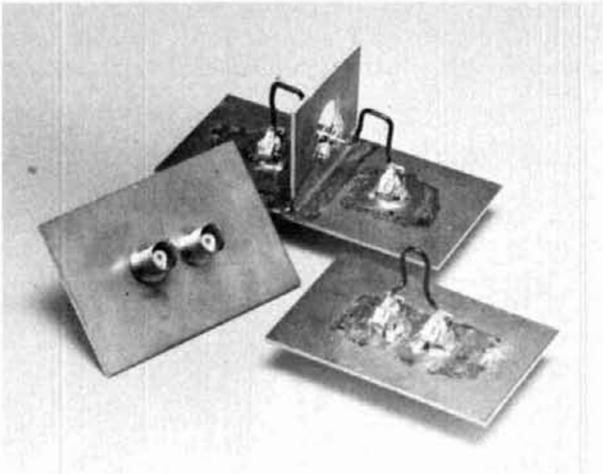


fig. 8. At 220 MHz, the inductors take the shape of hairpin inductors.

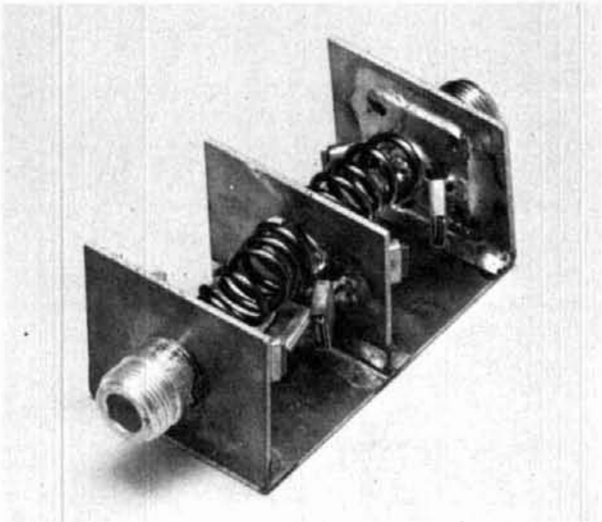


fig. 9. High-power filters require larger size wire and larger capacitors.

The response of the quarter-wave filter for various values of total Q is plotted in **fig. 6**.

The simple quarter-wave pi section may be thought of as consisting of two L-section matching networks, with the first L-network transforming the source impedance of 50 ohms to a lower value and the second L-section transforming this virtual impedance back to 50 ohms. If the network has a Q of 1, the virtual impedance will be 25 ohms. The value of the virtual impedance depends on the circuit Q:

$$R_{virtual} = R_{source} / (Q^2 + 1) \quad \textbf{(11)}$$

The half-wave filter in **fig. 1** is formed by cascading two quarter-wave filters. The shunt capacitors at the junction of the two quarter-wave filters may be combined into a single capacitor. As the power through the filter is increased, it is better to use two capacitors to support the increased current.

construction

At VHF and UHF, the ground plane of a filter must be given careful thought (see **figs. 7** and **8** and **table 1**). Appreciable inductance in the ground path will cause extra resonances to appear, especially at the higher frequencies. Harmonic energy must not be allowed to "sneak around" the filter due to extraneous ground paths. The capacitors must also have low-inductance leads. Metal-clad, uncased precision mica and teflon capacitors[5,6] can be used at VHF to minimize this lead inductance by soldering the case directly to the ground plane. The coils[7,8] are self-supporting

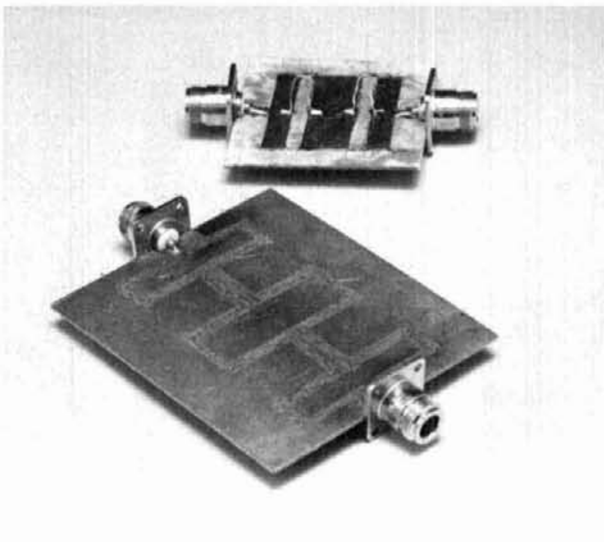


fig. 10. Microstripline filters use either printed or hairpin inductors.

and wound with No. 14 formvar-covered wire. Higher power filters (**fig. 9**) require larger wire and more capacitors in parallel to handle the increased current.

432- and 1296-MHz quarter-wave filters can use a microstripline structure with either (**fig. 10**) printed or hair pin inductors. The lumped capacitors are shaped to have minimal series inductance and the pc inductors are formed by "necking down" the center conductor (0.025-inch wide and 1.225 inches long at 450 MHz and 0.424 inches long at 1.3 GHz.) Type N launchers were added at the edge of the printed circuit boards.[9] **Table 2** includes dimensions for these same two filters using hair-pin inductors. The experimental results, comparing hairpin inductors with etched printed lines, are shown in **fig. 11**.

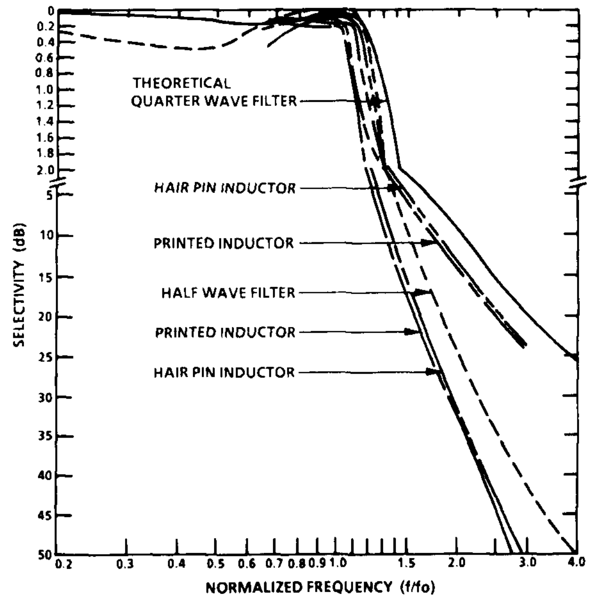
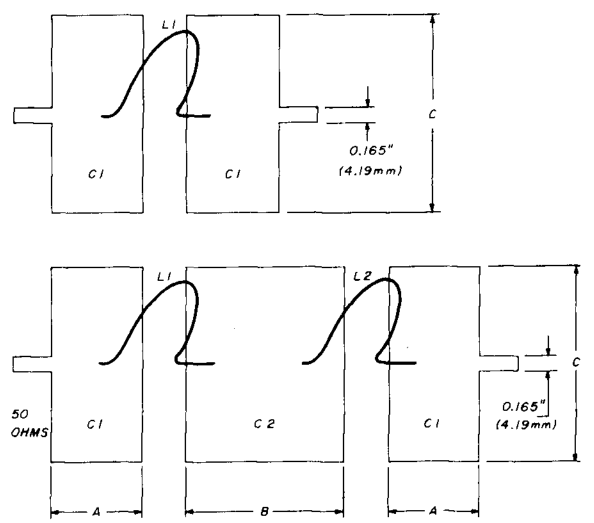


fig. 11. Experimental results for 450-MHz stripline quarter-wave and half-wave filters.

adjustment

Because most hams don't have sweep generators for checking filter response at the second, third, and fourth harmonics, it's best to construct simple VHF filters using lumped elements, which can be readily adjusted using a grid-dip meter. If reasonable construction practices are followed, one can expect a certain minimum guaranteed performance at the harmonics because adjustments have been made to ensure minimum loss at the design frequency. The simple quarter-wave filter is adjusted to the design frequency by shorting out a capacitor at either end of the pi network and adjusting the inductor for resonance, with the source and load impedances removed, as shown in **fig. 12A**. This effectively forms a parallel resonant circuit with C and L. The short circuit should be placed close to the common ground plane to decrease series inductance. Using a grid-dip meter, adjust the coil to resonate with the open capacitor at the design frequency. Adjust the half-wave filter in a similar manner by shorting the "double-value" capacitor and then adjusting each coil to resonance, as in **fig. 12B**. Adjust the three-quarter wave filter in a similar manner, as shown in **fig. 12C**. The center coil is simply adjusted to physically resemble the outer coils. Each of the filters for which data is shown in **fig. 4** was adjusted in this manner and then measured with no further peaking.

The coils may also be adjusted for resonance with-



Design Frequency	Dimensions			Values				
	A	B	C	C1	C2	L1,2	Height	Width
450 MHz	0.334"	0.694"	2.0"	7.07 pF	14.1 pF	17.7 nH	1/2"	1/4"
1,300 MHz	0.228"	0.472"	1.0"	2.5 pF	4.9 pF	6.1 nH	1/4"	1/8"

Table 2. Hairpin inductor multiple-quarter-wave filter dimensions.

out the short circuit. The inductor in the quarter-wave circuit of **fig. 12A** will resonate with the series combination of the end capacitors. The value of capacitance will then be one-half the value of either capacitor, with a resonant frequency of

$$f_{resonant} = \sqrt{2}\ fo = 1.414\ fo \qquad (12)$$

The resonant frequency is 76 MHz, for example, for a 6-meter low-pass filter designed for an upper cutoff frequency of 54 MHz. The half-wave circuit shown in **fig. 12B** may be adjusted without using a short in a similar manner if only one inductor is connected at a time. The resonant frequency formed by 2C, L, C is

$$f_{resonant} = \sqrt{3/2}\ fo = 1.225\ fo \qquad (13)$$

which is 66 MHz for an upper cutoff frequency of 54 MHz. If both inductors are present, the circuit will resonate at $\sqrt{2}\ fo$. *The resonant circuit will be composed of a capacitor of 2C in parallel with two series circuits of L and C.*

Hairpin inductors are adjusted for minimum loss using the transmitter and a power meter. As the hairpin is adjusted closer to the ground plane, the resonant frequency is decreased. The inductance is

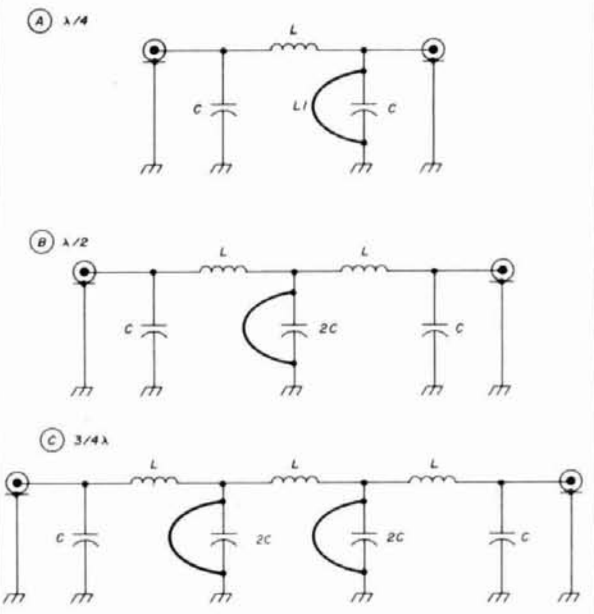


fig. 12. (A) The quarter-wave filter is adjusted by forming a parallel resonant circuit. (B) The half-wave filter is adjusted by resonating each end section. (C) The three-quarter wave filter center inductor is adjusted to resemble the end sections.

decreased, but the shunt capacity increases by a greater amount. The insertion loss of the multiple quarter-wave filter increases if low quality components are used. Coils typically have a lower inherent *Q* than capacitors. The dissipative insertion loss for a quarter-wave filter is given by

$$\text{Dissipative Loss (dB)} = 10 \log \left[1 - (Q_T / Q_{COIL})\right] \qquad (14)$$

The loss for a half-wave filter is simply twice the loss of a quarter-wave filter.

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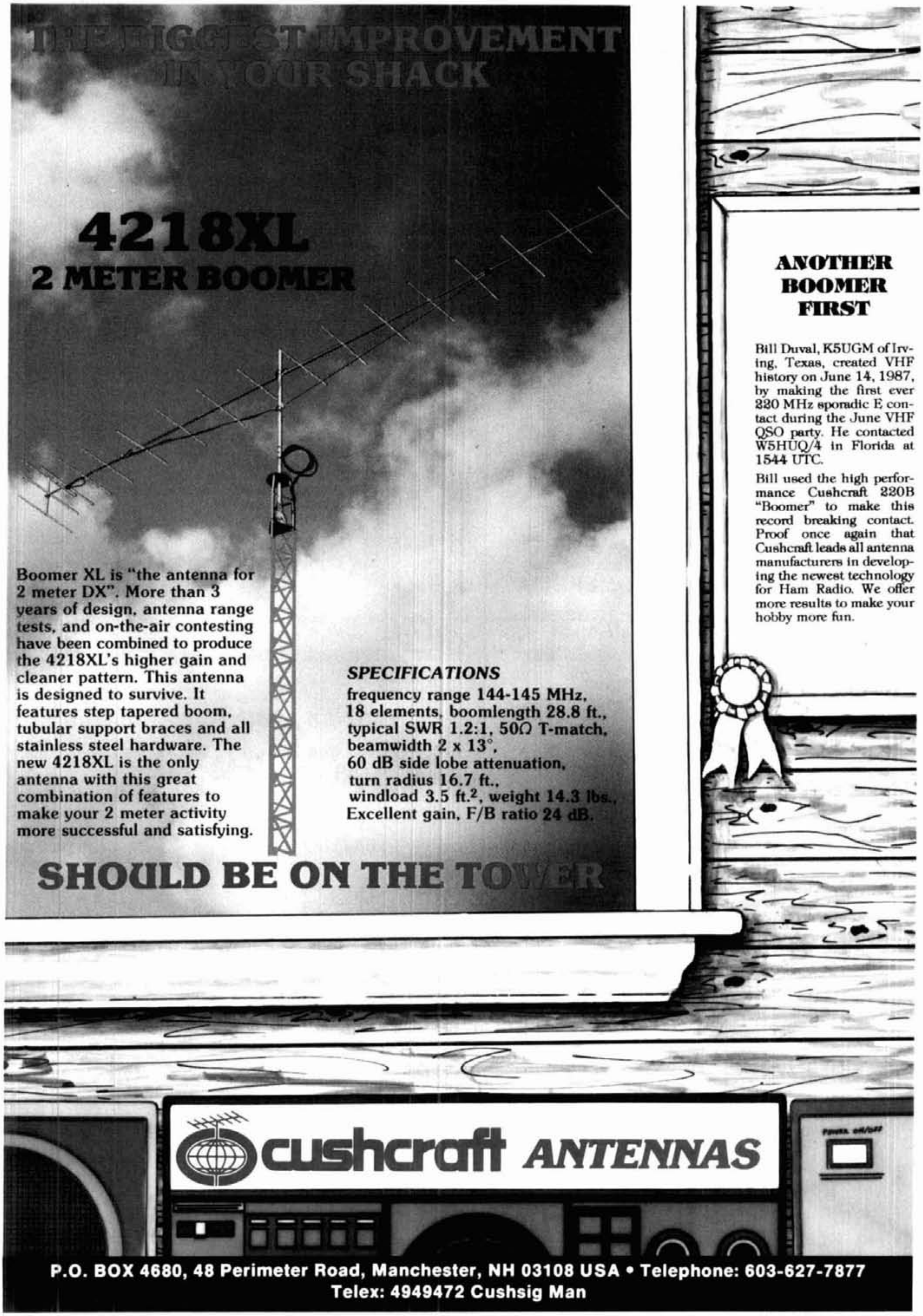
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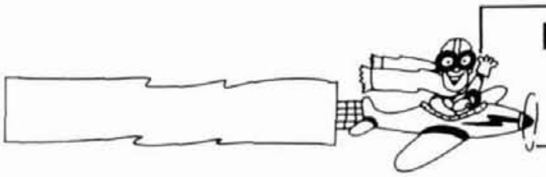

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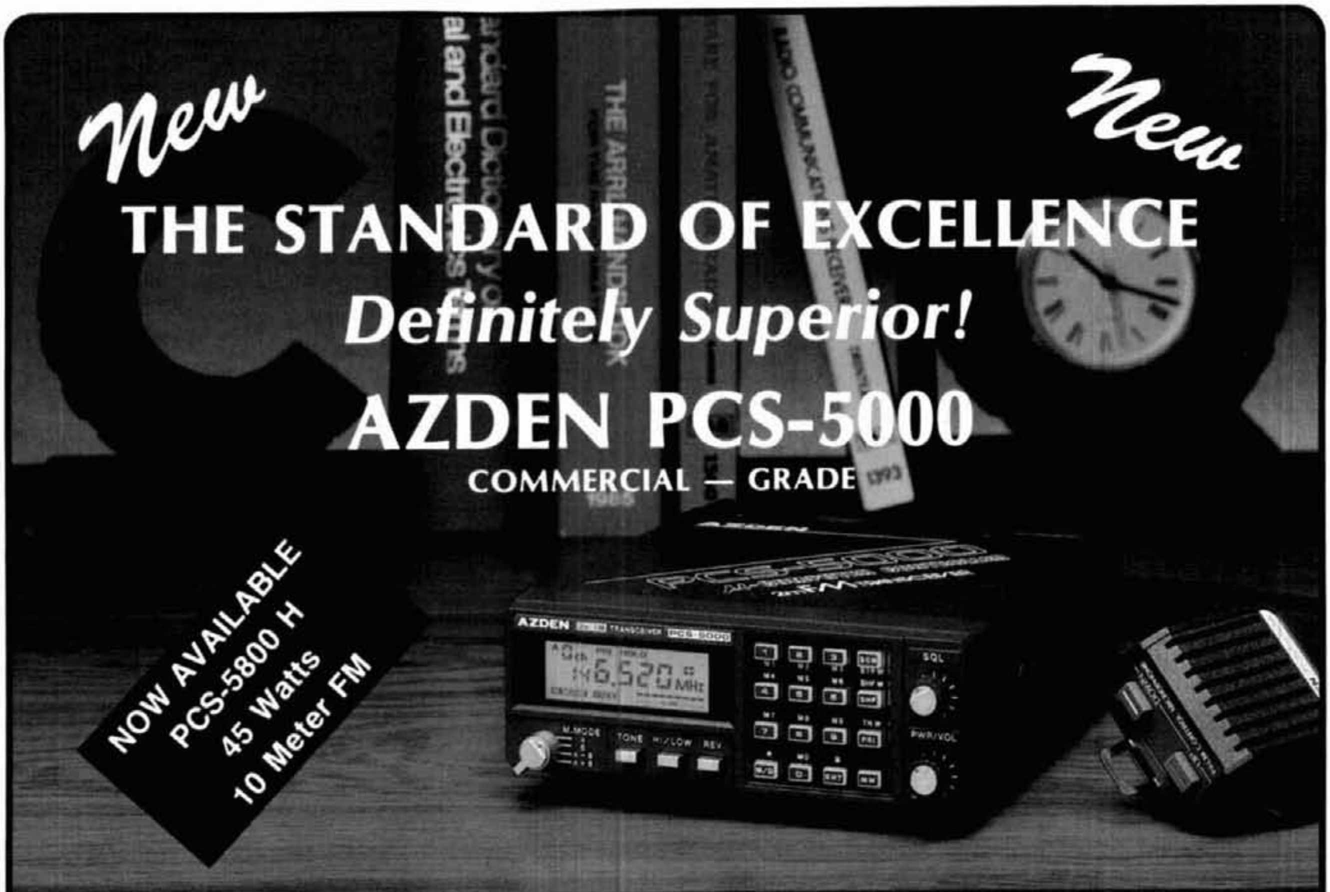

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PRACTICALLY SPEAKING ... Joe Carr K4IPV

revisiting the "poor man's spectrum analyzer": digitally generating sawtooth (and other) waveforms

In the March, 1987 column we discussed the "Poor Man's Spectrum Analyzer," which I built from an article published by W4UCH.[1] The design was originally put together by Murray Barlowe, WA2PZO, of Science Workshop.[2] In that column I mentioned that the sawtooth generated for that project left something to be desired, and offered a digitally generated improved sawtooth generator design to anyone who sent me a No. 10 SASE. Nearly 30 people wrote to me either via *ham radio*, my old callbook QTH, or my new QTH (see end of this article). As a result, I've decided to publish that circuit here. The response to my offer delighted me because it indicates that the doomsayers are wrong: Amateur construction is not dead!

Figure 1 shows part of the problem with the original sawtooth generator circuit. In my previous column on this subject, I showed several different sawtooth waveforms that were worse than **fig. 1**; this version is the *best* case. The waveform has two defects which adversely affect the operation of the spectrum analyzer. First, the rising ramp part of the sawtooth isn't linear. Because the original design was a capacitor charge/discharge circuit in the form of a Miller integrator, the ramp naturally has a shape like the normal capacitor charge waveform. What's required of a proper sawtooth is a linear ramp. The second defect is the fall-time: it's too long. Use of a few low-cost digital components produces a better sawtooth waveform.

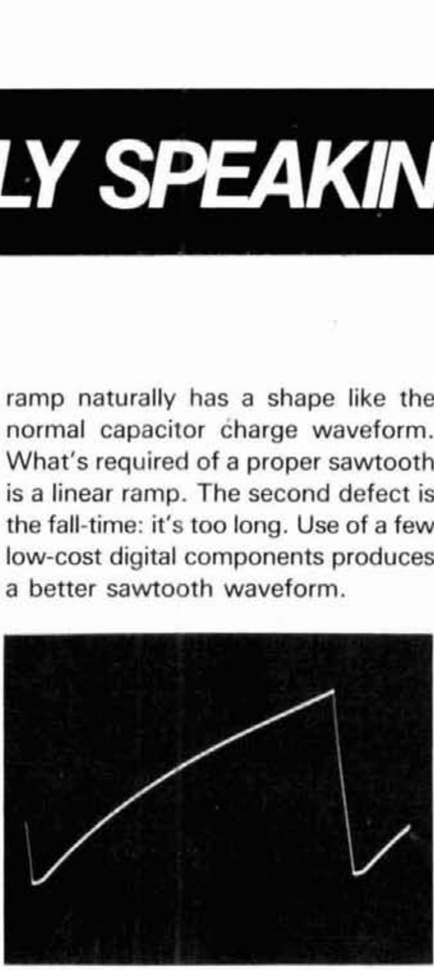

fig. 1 Best waveform available from the sawtooth generator.

The circuit for the new sawtooth generator is shown in **fig. 2**. The heart of this circuit is U1, a DAC0806 eight-bit digital-to-analog converter (DAC). This DAC, based on the Motorola MC-1408 family of DACs, was selected because it's well behaved and available through mail order sources such as Jameco Electronics[3] or in blister packs through Jameco's local distributor line of *Jim-Paks*.

A DAC produces an output voltage that is proportional to the reference voltage or current and the binary word applied to its digital inputs. The transfer function of this DAC is:

$$I_o = I_{REF} \cdot \frac{A}{256} \qquad (1)$$

where:

I_O is the output current from pin 4;

I_{REF} is the reference current applied to pin 14, and

A is the decimal value of the binary word applied to the eight binary inputs (pins 5-12).

The reference current is the reference voltage divided by the series resistor value at pin 14. In data systems the reference voltage is a precision, regulated potential. But in this case we don't need that precision, so we can use the V+ power supply as the reference voltage. Therefore, the reference current is (+12 Vdc)/R4. With the value of R4 shown (6800 ohms), I_{REF} is 0.0018 amperes, or 1.8 mA. Values from 500 μA are permissible with this device. If you elect to change the reference current, be sure to keep R4 equal to R5.

The reference current sets the maximum value of output current, I_O. When a full-scale binary word (11111111) is applied to the binary inputs, the output current I_O is:

$$I_o = (1.8\ \mu A) \cdot \frac{255}{256} = (1.8\ \mu A) \qquad (2)$$

$$\cdot\ (0.996) = 1.78\ \mu A$$

the DAC0806 is a current output DAC, so we must use an op amp current-to-voltage converter in order to make a sawtooth voltage function. A circuit that accomplishes this is an ordinary

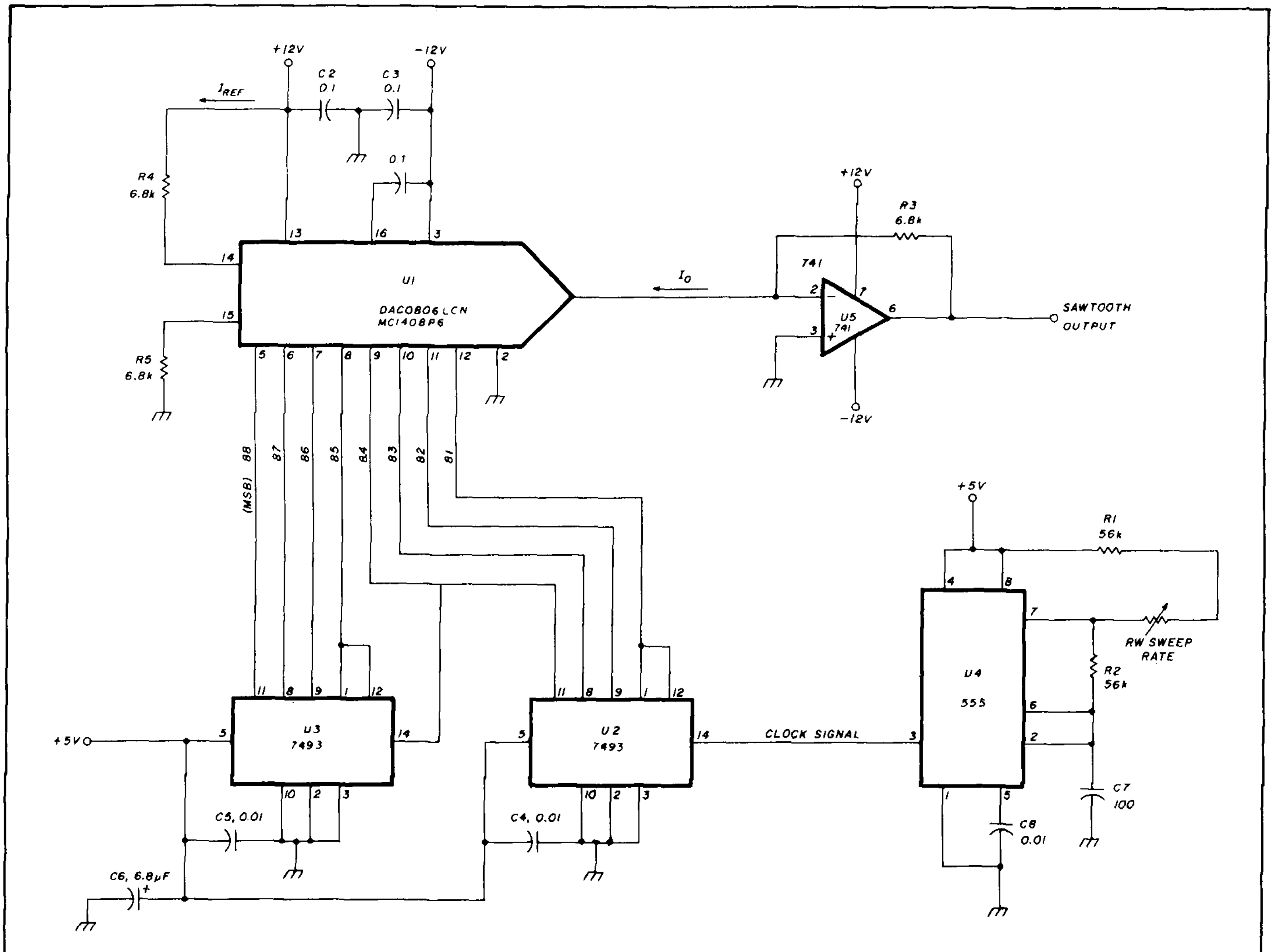

fig. 2. Digital sawtooth generator circuit.

inverting follower without an input resistor. The output voltage (V_O) will rise to a value of ($I_O \times R3$).

The waveform produced by this circuit is shown in **fig. 3**. This waveform has a period, T, of about 5 ms (1/T = 200 Hz), and an amplitude of about 5 volts. In **fig. 3A**, notice that the falling edge is too fast for the oscilloscope camera to photograph (contrast this with the **fig. 1** waveform). The leading edge of this latter waveform also represents an improvement. An expanded view of the positive-going ramp is shown in **fig. 3B**.

The actual output waveform is a staircase of binary steps, each equal to the 1-LSB (Least Significant Bit) current of U1 (or the 1-LSB voltage of V_O). The 1-LSB voltage is the smallest step change in output potential caused by changing the least significant bit (B1) either from 0 to 1, or from 1 to 0. You don't see it in **fig. 3** because the frequency response of the 741 operational amplifier used for the current-to-voltage converter acts as a low-pass filter to smooth the waveform. If a higher frequency op amp is used, then a capacitor shunting R3 will serve to (low-pass) filter the waveform. Although I haven't tried other op amps in this application, I suspect a -3 dB frequency (f) of 1 or 2 kHz will suffice to smooth the waveform. The value of the capacitor is calculated from:

$$C = \frac{10^6}{6.28\ R3 \cdot f} \qquad \textbf{(3)}$$

where:

C is the capacitance in microfarads;

f is the −3-dB cutoff frequency in Hz;

$R3$ is expressed in ohms.

This circuit is synchronized by a clock oscillator consisting of a single 555 IC timer. Although not a TTL device, the 555 is TTL-compatible when the V+ potential applied to pins 4 and 8 is limited to +5 Vdc. The 555 is connected in the astable multivibrator configuration and generates a +4 volt amplitude series of pulses. The operating frequency is set by three resistors (R1, R2, and RW) and capacitor C7. The actual frequency is:

$$f = \frac{1.44}{((R1 + RW) + 2R2)\ C7} \qquad \textbf{(4)}$$

where:

f is the frequency in Hz;

C7 is in farads;

R1, R2 and *RW* are in ohms.

Select a clock frequency that is 256 times the desired sawtooth sweep frequency. For most spectrum analyzer projects the sweep frequency range will be 10 to 200 Hz. Slower rates make viewing on the CRT screen difficult, while faster rates may tend to "ring" the bandpass filter used in the i-f amplifier section.

waveform selection

As electronic music buffs will testify, we can get almost any waveform we need by applying the right binary words to the digital inputs of the DAC0806. Because I wanted a sawtooth waveform, the DAC inputs were connected to the outputs of an eight-bit binary counter built from a pair of 7493 TTL base-16 counter chips. Each chip is a four-bit counter, so they are cascaded to produce the eight-bit binary word needed to drive the DAC. If you want a detailed description of this chip, I recommend Don Lancaster's book *TTL Cookbook*.[4] The function of this counter is to increment in steps from 00000000 to 11111111 under control of a clock signal applied to the input (pin 14) of U2. You could use any eight-bit counter that outputs a TTL-compatible signal in place of the 7493 devices that I selected. The 7493 was chosen for the best of all engineering reasons: I had a pair of them in my junkbox.

If you want a triangular waveform, then it's possible to replace the 7493 devices with a base-16 up/down counter chip. Arrange the digital control logic to reverse the direction of the count when the maximum state (11111111) is sensed.

There are two ways to generate waveforms other than a sawtooth or triangle, and both of them involve using computer memory. The binary bit pattern representing the waveform, and then output in the right sequence, are stored in memory. One method uses a ROM that you pre-program with the bit pattern. A binary counter circuit connected as an address generator selects the bit pattern sequence. The second method stores the bit pattern in a computer, then outputs it under program control via an eight-bit parallel output port. This method is usable for both generating special waveforms and for linearizing the tuning characteristic of the spectrum analyzer.

fig. 3A. Waveform from the digital sawtooth generator: three successive waves.

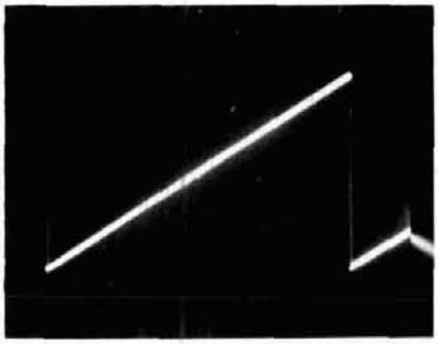

fig. 3B. Waveform from the digital sawtooth generator, expanded to show greater detail.

The varactor TV tuner that forms the basis of this project has a nonlinear voltage vs. frequency characteristic. This is due to both the nature of varactor diode voltage vs. capacitance curves, and to the fact that the change of frequency in an LC tank circuit is proportional to the square root of the change in capacitance. For this reason I suspect that the actual mathematical function of the curve is basically parabolic (i.e., it looks as if it might approximate a quadratic "$aX^2 + bX + c$" function).

There are a couple of methods that can be used for the linearization process. First, the analog method involves the use of an XY/Z analog multiplier divider circuit (a special IC). These devices can be connected as a "square rooter" stage. There are two problems with this: first, that the values of the constants must be determined (which is not so easy) and second, that many of these ICs tend to be either expensive or temperamental, especially to changes in temperature. However, there is a digital solution.

The digital solution to the linearization problem involves storing a look-up table in either a ROM or computer memory. I learned this system in a medical electronics laboratory where it was once used to linearize low-level pressure transducer measurements. **Figure 4** shows a generic version for a voltage that represents some parameter P, which in our case might be the frequency of the spectrum analyzer local oscillator. The actual nonlinear curve could be any shape, including parabolic, while the "ideal" curve is a linear function $Y = mX + b$, where $b = 0$. The idea is to measure the ideal voltage (which in our case is generated by the sawtooth or tuning control) with an A/D converter, and then output a binary word to a DAC that represents the actual required voltage. For example, at point P1 the ideal voltage is 0.9 Vdc, while the actual voltage is 0.68 Vdc. When the computer senses an ideal voltage of 0.9, it creates an actual voltage of 0.68 in order to drive the tuning to the correct frequency.

Another concept is to go all digital, except for the DAC that creates the actual tuning voltage. We could, for example, divide the spectrum up into N segments and store the binary codes for the correct tuning voltages in memory for each discrete point. The value of N corresponds to the bit length of the DAC. **Figure 5** shows a simplified block diagram of such a system. Tuning is controlled by a clock that drives the binary counter. The N-bit binary word output from the counter is routed to the address pins on the ROM. Contained in the ROM is the bit pattern for each of the 2^N discrete vol-

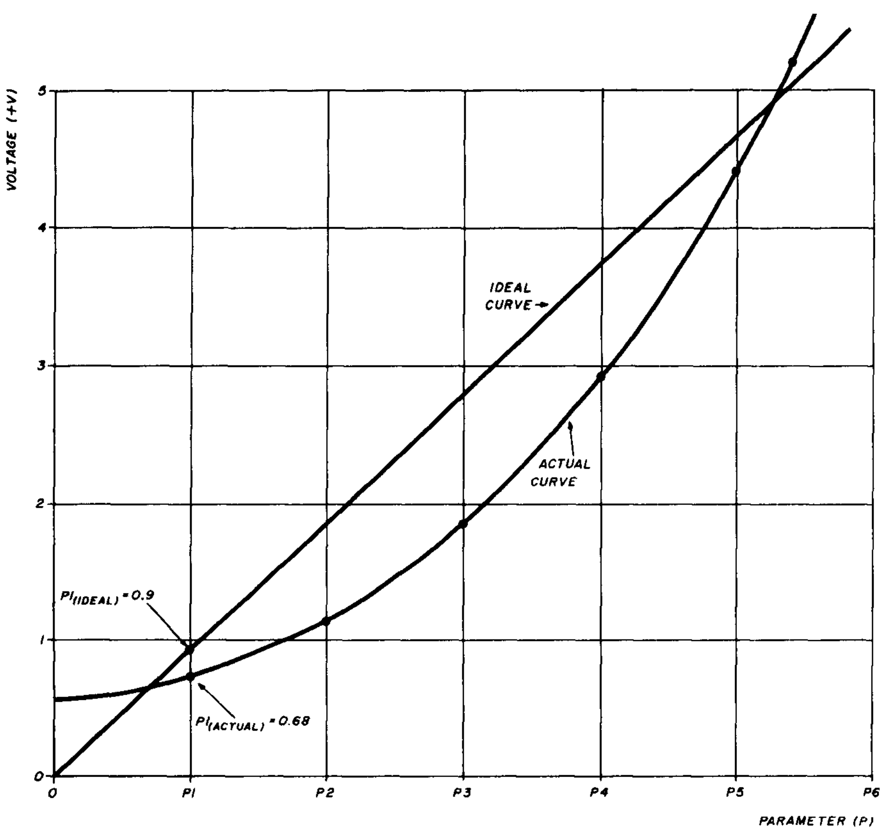

fig. 4. Example of linearization process.

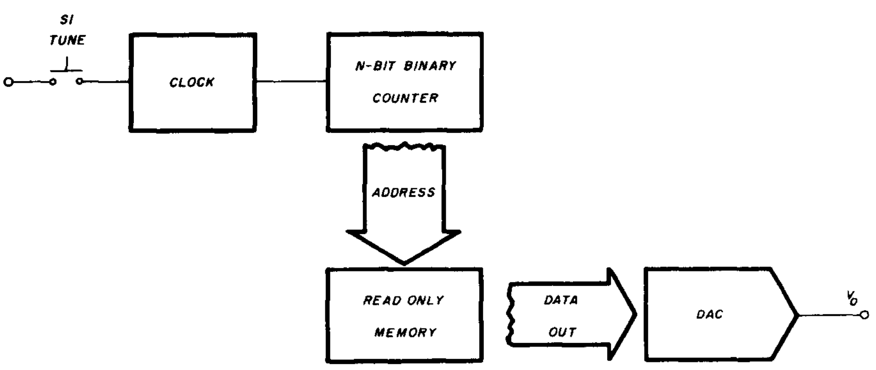

fig. 5. Suggested starting point for an all-digital linearizer.

tages that can be generated by the system. The correct binary word corresponding to this calibrated discrete potential is routed to the DAC, which generates the correct voltage. I haven't developed this circuit, but suspect that it wouldn't be too difficult once an accurate and correct voltage vs. frequency chart is known for any given tuner (that curve is the source of the data that is contained in the ROM).

a note from WA2PZO

After my initial column on this topic appeared, WA2PZO sent me a note on the feedthrough capacitors used in the project. (I had complained about the high cost, but have since learned that Dick Smith Electronics[5] stocks them for less than 50 cents each.) Murray informs me that he no longer advises bypassing *all* of the leads because the capacitance tends to integrate the waveform, makes the receiver less usable as a monitor receiver, and introduces a little instability. If you installed bypass capacitors on the leads into the shielded i-f box, remove all of them except the one on the + 12 Vdc regulated power supply line.

One reader wrote about an "inverted scope image" problem, which I am at a loss to describe. If anyone has had this problem and solved it, then please pass the solution on to me and I'll pass it on to the affected reader. If it's of sufficient interest, perhaps we'll find space to cover it in a future issue.

WA2PZO now has a tracking generator kit available for the "Poor Man's Spectrum Analyzer." It consists of a modified tuner and some extra parts that go on the SW-6006 i-f board. Write to him for details. In the meantime, I'm planning to build it and evaluate it in this space sometime in the future. I don't want to devote much space to this project because of all the other pressing issues that interest readers . . . but a tracking generator has definite possibilities!

references

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2. Robert M. Richardson, W4UCH, "Low-Cost Spectrum Analyzer with Kilobuck Features," *ham radio*, September, 1986, pages 82-90.
3. Jameco Electronics, 1355 Shoreway Road, Belmont, California 94002. (Catalog available for $1.00 postage and handling.)
4. Donald Lancaster, *TTL Cookbook*, Howard W. Sams & Co., Inc. Available from Ham Radio's Bookstore, Greenville, New Hampshire 03048; $14.95 plus $3.50 shipping and handling.
5. Dick Smith Electronics, P.O. Box 2249, Redwood City, California 94064. (148-page catalog available for $1.00 postage and handling.)

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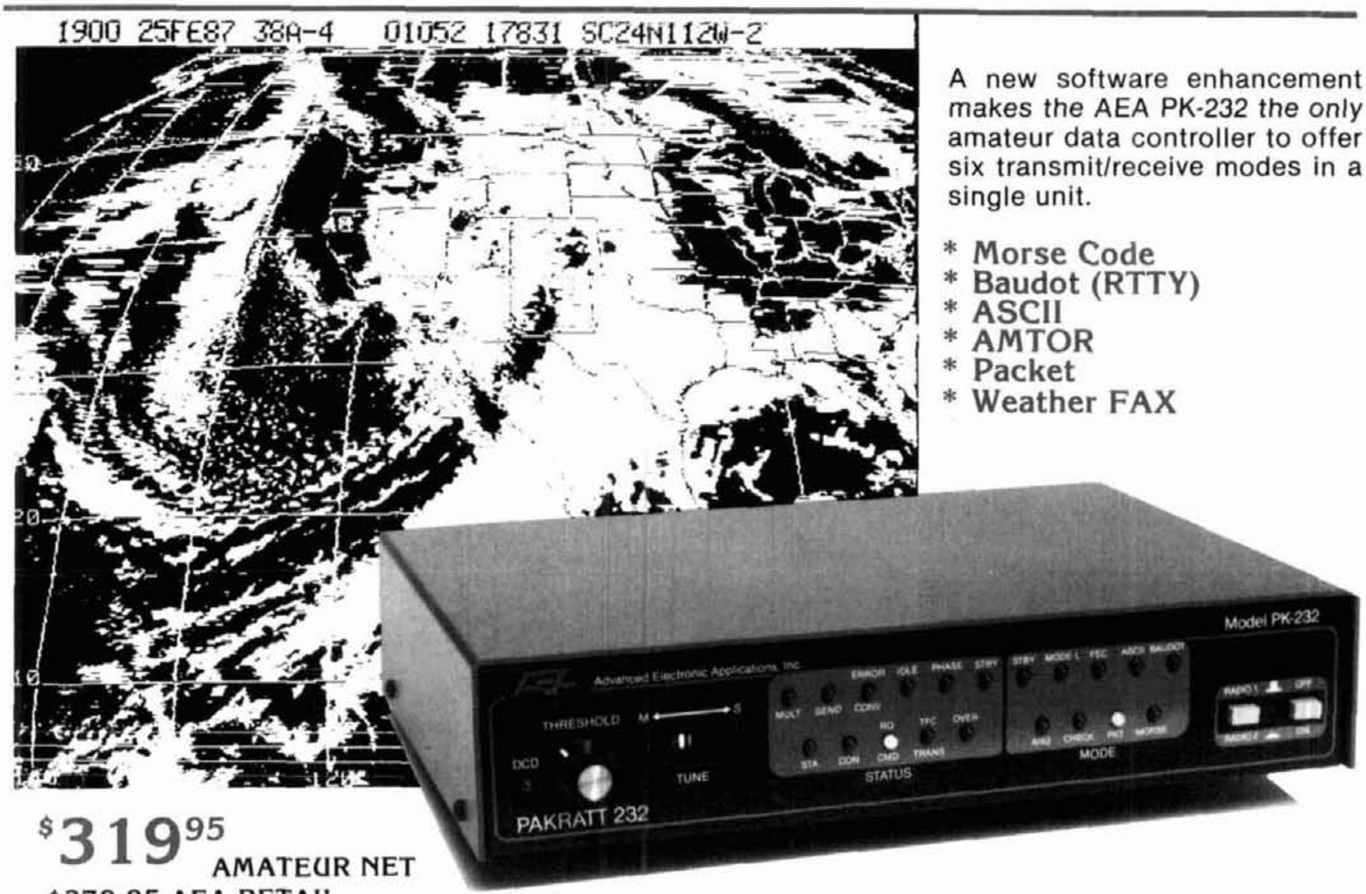

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ham radio TECHNIQUES

Bill Orr W6SAI

happy days are here again?

Something happened last spring. After many months of mediocre conditions, the DX bands came alive. Twenty meters was open until almost midnight, alive with mouth-watering signals. Long-distance DX contacts, heretofore a weak, watery S1 to S2, were now booming in S9-plus. I amazed myself by working a UA1 on 15 meters, something that hadn't happened for many years. DX signals were even coming through on 10 meters!

Although this activity decreased somewhat with the summer lull and high static level, it seems to be picking up with increased vigor this fall. For Amateurs licensed within the last five years, radio conditions over the next several years — as the sunspot cycle increases rapidly — are going to hold big surprises. . . you ain't seen nothin' yet!

the two-band loop antenna

It's not easy to get an effective DX antenna that will work on both 80 and 40 meters. By "80 meters," I mean both CW operation at the low end of the band and SSB operation near the DX slot at 3.8 MHz. It looks as if Jack McCullough, W6CHE, has found an answer — providing you have a modest tower and a small amount of real estate. Jack's solution to the 80/40-meter dilemma is shown in **fig.**

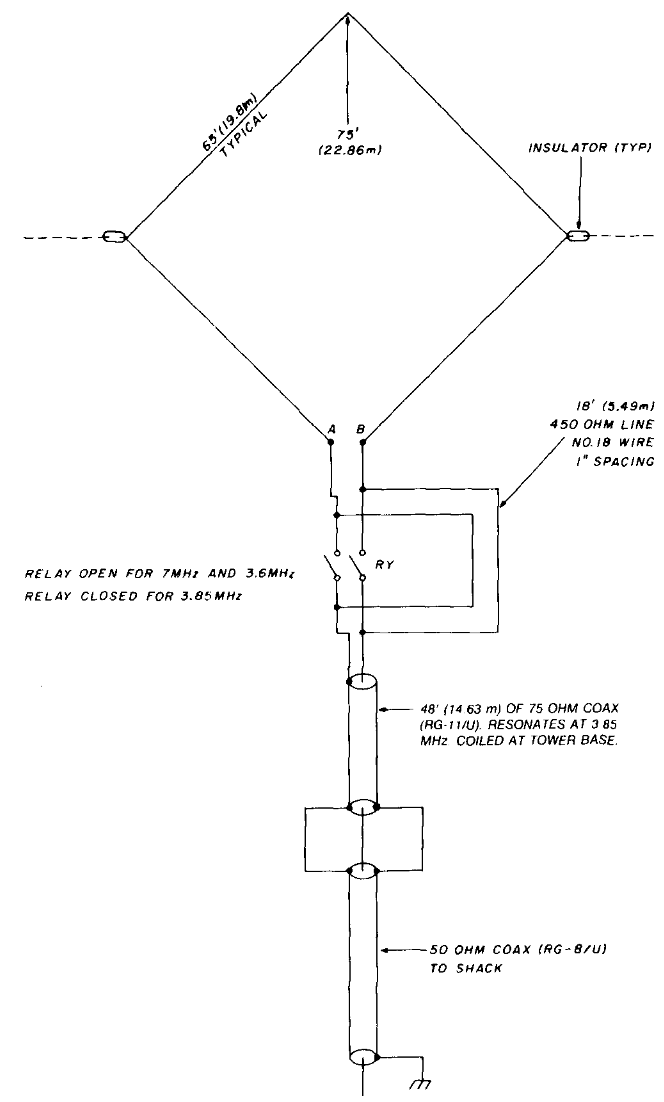

fig. 1. W6CHE 40- to 80-meter quad loop.

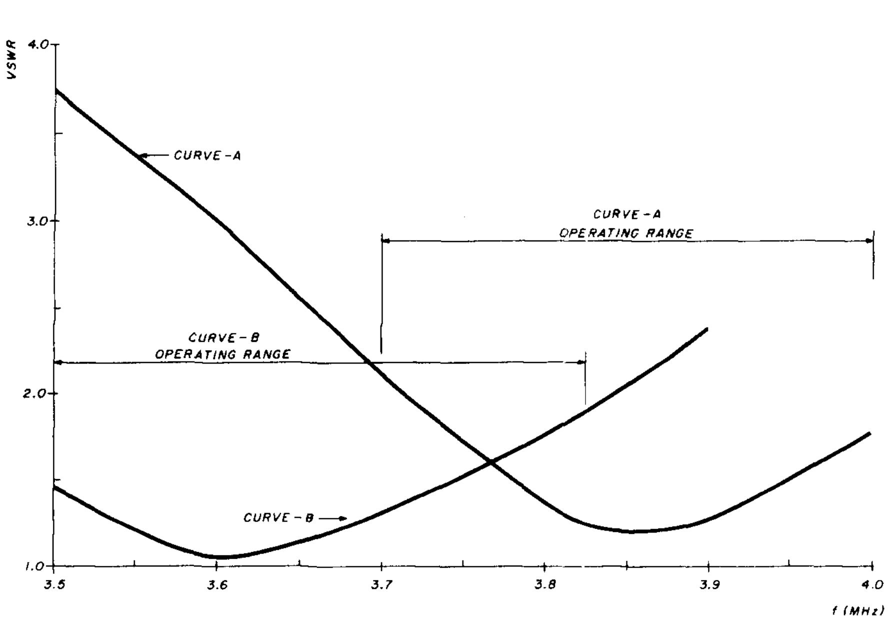

fig. 2. Operating range of W6CHE loop with relay (A) closed or (B) open.

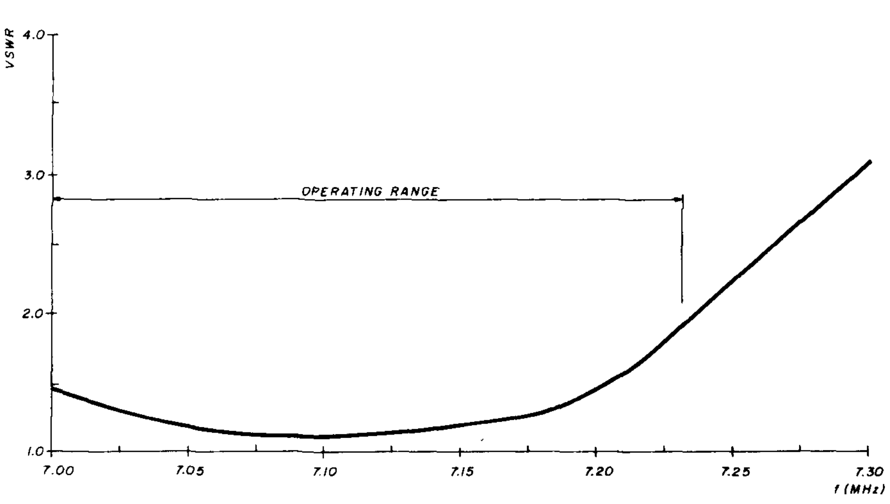

fig. 3. Operation of W6CHE loop at end of 40-meter band (relay open).

1. The basic antenna is a single 80-meter diamond-shaped Quad loop measuring 65 feet on a side and hung from the top of a 75-foot tower. Since the overall height of the diamond from base to apex is about 90 feet, the loop plane is tilted out at the base, away from the tower. The assembly, thus, is not in the vertical plane. If you have a higher tower, the loop can be mounted in the vertical plane.

The loop is fed with a 50-ohm coax line, plus a 48-foot section of RG-11/U (75 ohm) coax which serves as a matching transformer. The line is cut to 3850 kHz with the aid of a dip meter.

80-meter operation

A double-pole relay is placed between the matching section and the feedpoints of the loop. When the relay is closed, the loop is resonant at 3.8 MHz. When the relay is open, the loop is lengthened by means of an 18-foot section of 450-ohm open-wire line. The loop is now resonant near 3.6 MHz (see **fig. 2**). Thus, by the flick of a switch, the antenna can be made resonant at either end of the 80-meter band, providing a low value of SWR to the transmitter.

40-meter operation

Operation across the lower portion of the 40-meter band is possible when the relay is either open or closed. The best situation is shown in **fig. 3**, with the relay in the open position. The operating range, as defined in the curves, is about 7.0 to 7.25 MHz.

The secret of moving the Quad loop about in frequency is the length of the matching stub. Obviously a different length stub is required for operation at the high end of the 40-meter band.

The final W6CHE loop design is shown in **fig. 4**. Two relays and two stubs are used. One stub is 15 feet long and the other is 4 feet long. In series connection, they represent a stub about 19 feet long. The stubs are switched in and out of the circuit by means of a two-pole, three-position rotary switch at the operating position. Power is applied to the relays by means of a separate switch which energizes the dc supply. Switching sequence for the various frequency ranges is listed in **table 1**.

a temporary wire antenna for 80, 40 and 20 meters

A friend of mine moved into a temporary location and wanted to get on the high frequency bands with an unobtrusive antenna. He and I thought about it for a while and finally decided on an end-fed wire working against a radial ground system (**fig. 5**). On 160 meters, the antenna is about 3/16 wavelength long; on 80 meters, about 3/8 wavelength; on 40 meters, about 3/4 wavelength; and on 20 meters, about 3/2 wavelengths. On all bands except 160 meters, the feedpoint impedance runs between 65 and 180 ohms. On 160 meters, it's about 10

Table 1. Switching sequences for W6CHE loop.

Frequency Range (kHz)	SW1	SW2	Total Stub Length
3500-3650	open	—	19 feet
3550-3750	closed	Position 1	15 feet
3700-3900	closed	Position 2	4 feet
3750-4000	closed	Position 3	—
7000-7125	open	—	19 feet
7125-7300	closed	Position 1	15 feet

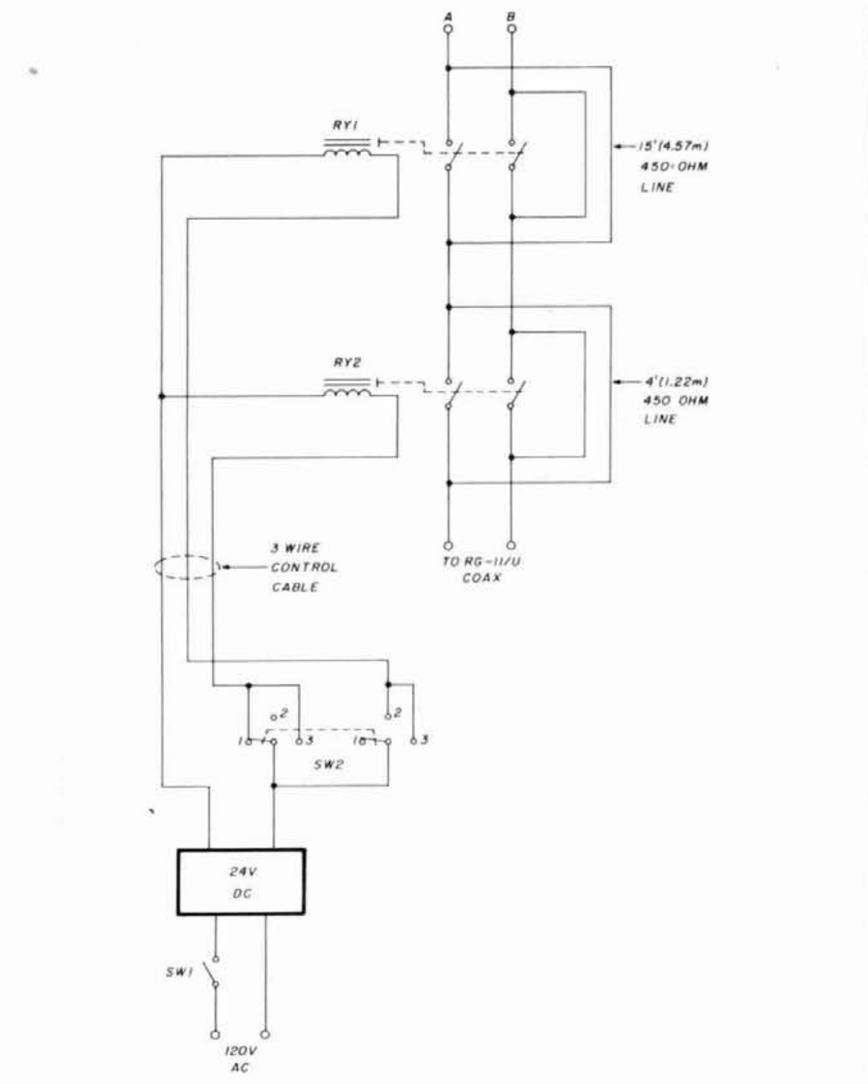

fig. 4. Dual-relay arrangement for operation on the different segments of the 40- and 80-meter bands (see table 1).

ohms. An L-network at the base is used to feed the antenna.

Successful operation depends upon a good radial ground termination at the base of the antenna. A combination of two ground rods, plus quarter-wave

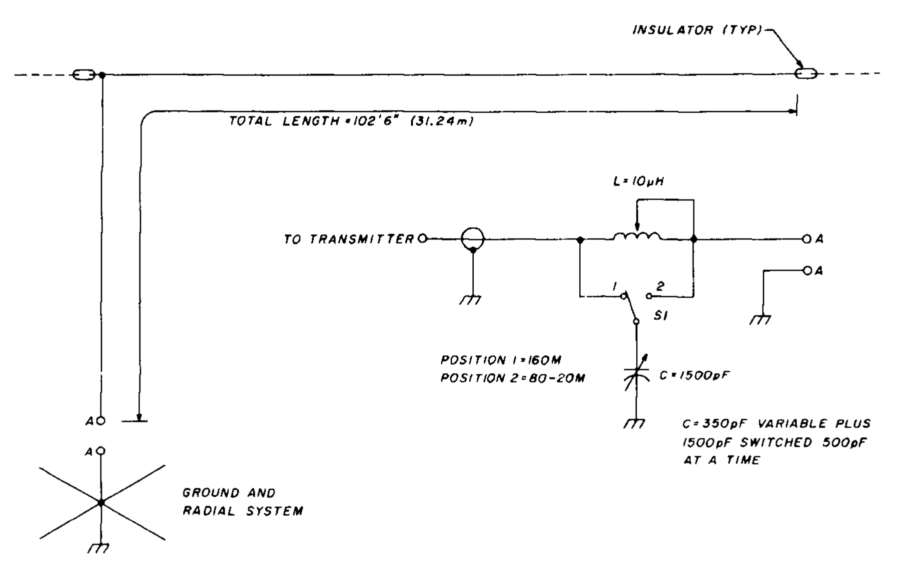

fig. 5. Multiband, end-fed wire antenna for 160 to 20 meters.

radials laid upon the surface of the ground will do the job. The more radials, the better.

In this particular installation, the vertical portion of the antenna is about 35 feet, or approximately a half-wavelength on 20 meters.

Since the antenna terminates just outside the radio room, the network is placed in a waterproof box that can be reached in seconds when a band change is desired.

The antenna was adjusted first on 80 meters. The terminals at A-A were shorted together with a one-turn loop and the antenna cut for resonance at 3.5 MHz, with the aid of a dip meter. The flat-top was pruned to achieve the proper electrical length. This makes the antenna slightly short for operation on 40 and 20 meters, but the L-network takes care of the situation. It also permits operation of the antenna at the high-frequency end of the 80-meter band with a low value of SWR at the transmitter. The L-network capacitor is reversed by S1 for 160-meter operation, and the frequency response without retuning on this band is only about 25 kHz.

While its performance on 20 meters isn't equal to that of a Yagi on a 60-foot tower, it does permit plenty of enjoyable QSOs in a location where a more robust and permanent antenna would be impossible to erect.

15-meter Yagi

I received a letter from "Mac" McDaniel, W4PFZ, that brought joy to my heart. Mac says:

Back in the February, 1955, issue of CQ, you described a two-element Yagi with data for making it a three-element array. I was living in Richmond, Virginia, at the time and made an exact copy of the beam. It had plenty of gain, and local hams were surprised at the front-to-back ratio, which seemed to be about 36 dB.

Over the course of many years I have moved frequently and the beam has been disassembled and reassembled several times. I now have the original beam up on a 55-foot wooden pole. Every time I check the front-to-back ratio on ground wave I come up with numbers between 32 and 38 dB.

I adhere to the philosophy of "if it ain't broke, don't fix it," and have never changed a single dimension since first building the beam in 1956. I've replaced the variable gamma capacitor several times and reset it for resonance at 21.3 MHz, which takes about 10 minutes.

The last time I reworked the gamma match, I did it with the beam near the ground, pointed up at the sky. It was easier than working atop the pole and the final result is no different than adjusting the match at the top of the pole.

I thought you might like to hear about the success obtained from following your construction information in an article written over 30 years ago!

Designed long before computer-aided programs were available, the beam Mac speaks about represents a configuration determined by field strength measurements made on a crude antenna range. The inner portions of the elements were made of 12-foot lengths of 1-inch diameter aluminum tubing and the tip sections were made of 7/8-inch diameter tubing. Elements were attached to the boom by means of 8 x 8-inch aluminum plates oriented diagonally so the actual contact with the boom and the elements was about 11 inches.

The ends of each center element were slotted with a hacksaw to a depth of about 1 inch and stainless steel hose clamps were tightened around the slots. A band of red paint was put around each outer section so it could be reassembled exactly as it was originally.

Since 15 meters is coming back to life, I'm reprinting my original Yagi design for those DXers who might want to build their own beam (**fig. 6.**).

The boom is a single section of heavy-wall tubing, 1 inch in diameter. Dimensions are given for resonance at 21.3 MHz.

The only adjustment required is that of the gamma matching device. Length and spacing of the gamma rod are set as illustrated and a small amount of power is fed to the beam via an SWR meter. The variable capacitor is adjusted for the lowest value of SWR. In some cases, it may be necessary to move the shorting strap between the driven element and the matching rod a few inches one way or the other to achieve a near-unity SWR figure.

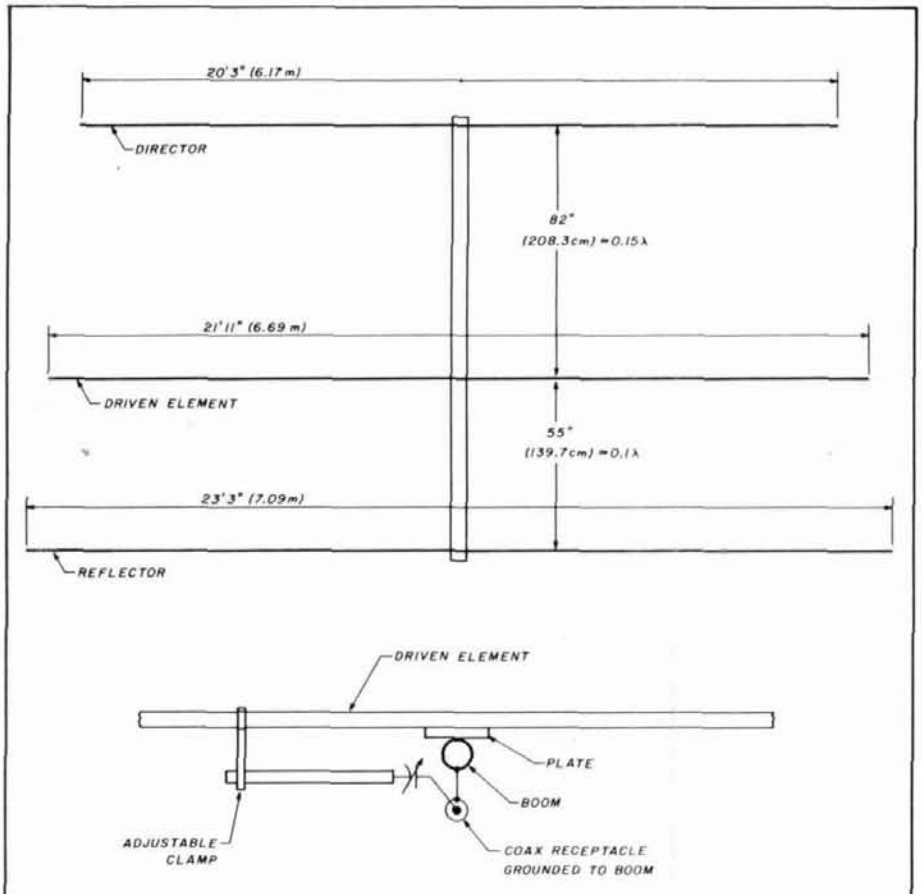

fig. 6. The W4PFZ version of the original W6SAI beam for 15 meters using 12-foot boom.

Although I've never done it, W4PFZ suggests that the beam can be adjusted on the ground by supporting it in a vertical position, with the director pointing up at the sky and the reflector clear of the ground by a few feet. This sounds a lot easier than hanging by your heels atop the tower to adjust the gamma capacitor!

In the original design, the gamma capacitor was mounted inside a 3 x 4 x 5-inch aluminum "minibox." It was isolated from the box by means of an insulating plate. The box was grounded to the antenna boom. A coax fitting for the feed line was placed on one end of the box and a ceramic feedthrough insulator at the other end of the box supported the gamma rod. The shaft of the capacitor could be adjusted through a hole in the box. After adjustment, the hole was closed with several layers of tape to prevent water from entering the box. The seams of the box were coated with roofing compound for the same reason.

Commercial 6061 or aircraft alloy 2024 tubing are recommended for construction of the elements. To retard oxidation at the element joints, a special lubricant, such as the grease employed in industrial power installations that use aluminum conduits, is used. (Some of the trade names for this compound are *Penetrox,*® *Cual-aid,*® and *Ox-guard*®. The compound is smeared lightly over the tubes before they are joined.

I don't know whether many Amateurs build their own beams from scratch today, or if they buy pre-cut kits from a manufacturer. I'll be interested to hear if anyone duplicates this proven antenna and what kind of results they achieve with it. Good luck!

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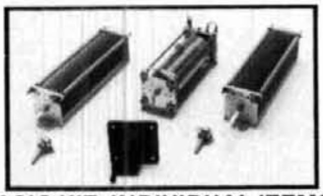

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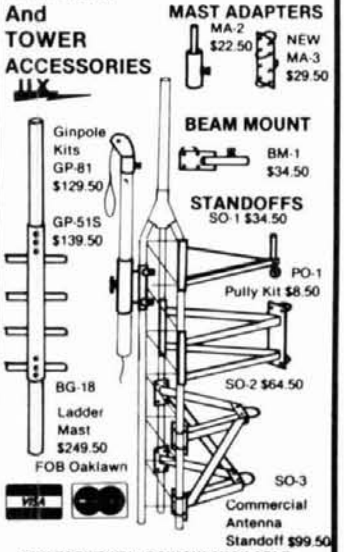

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minimum requirements for 2-meter EME: part 2

Last month's column was an introduction to 2-meter EME communications, including explanations of EME terminology.[1] With that information in place, we can concentrate on the minimum requirements, recommended equipment, and operating techniques.

the minimum station

As I stressed in earlier articles,[1,2,3] the goal should be to build a station that allows you to hear your own echoes if all conditions are favorable; I call this the "minimum station" (**fig. 1**). This setup includes the "built-in test" feature described in reference 1 so you'll be able to verify that your gear is functioning properly. You'll not only be able to have successful EME contacts — you'll be able to quickly evaluate system changes and improvements as well.

Table 1 shows the typical minimum parameters and equipment necessary. As you can see, the path loss is staggering compared with path loss on hf, where signals are typically attenuated only 75 to 175 dB. This is part of what makes EME communications such a challenging sport!

It may be worthwhile for those who are mathematically inclined to see how EME path loss is calculated. Sometimes the so-called "radar equation" is used[4]:

eqn 1:

$$R_{max} = [(P_t\ G\ A_e\delta) / ((4\pi)^2\ S_{min})]^{1/4}$$

where R_{max} is the range in kilometers, P_t is the transmitter power in watts, G is transmitter antenna gain in dBi, A_e is the effective aperture of the antenna in meters squared, δ is the radar cross section of the target in meters squared, and S_{min} is the minimum detectable signal in watts.

Because **eqn. 1** isn't easily adaptable for Amateurs on EME, I prepared **eqn. 2**, which is oversimplified and not applicable to the higher bands, where the sky noise is very low. This simplified "2-meter EME radar equation" is useful for evaluating the elements of a station that uses the same antenna for transmitting and receiving. The reference is the received signal level at the antenna feedpoint based on a 50-ohm impedance:

$$P_r = P_t + 2(G_a) - P_l \qquad \textbf{eqn. 2}$$

Where P_r is the received signal power in dBm (level with respect to 1 milliwatt), P_t is the transmitted power in dBm measured at the antenna feedpoint, G_a is the antenna gain in dBi referenced to the feedpoint, and P_l is the path loss in dB.

For example, let's evaluate the minimum station shown in **table 1**. P_t is the transmitted power at the antenna feedpoint, 500 watts or +57 dBm. G_a is the antenna gain, +20 dBi. P_l is the nominal path loss, or 252.5 dB. Therefore, the received power level at the feedpoint is approximately −155.5 dBm (0.0038 microvolts), a very weak signal! (More on this shortly.)

Antenna gain deserves some further comment. As mentioned before, when calculating EME performance, antenna gains are usually specified in dBi (dB over isotropic), since the path loss is specified in the same terms. Just add 2.15 dB to any antenna gain specified in dBd (gain over a dipole) and you'll be all set. If you use stacked antennas, you'll have to estimate the overall system gain (see references 5 through 7). When estimating antenna system gain, don't forget to subtract the phasing line loss.

As discussed in last month's column, it is common EME practice to use the same antenna on both transmit and receive. The most important EME parameter in **eqn. 2** is antenna gain; every time the EME antenna gain increases by 1 dB, the total system performance improves by 2 dB (1 dB stronger on transmit and 1 dB on receive). Therefore, **eqn. 2** clearly shows that you should spend most of your EME efforts on perfecting your antenna system.

The transmitted power is well understood. Any increase here is on a dB-for-dB basis. Generally, increasing transmitted power helps the other station hear you better. If you have a 1-dB feed line loss between the output of your final power amplifier and the antenna system, a typical setup on 2 meters, 625 watts is required in the shack so that the required 500 watts will be present at the antenna. Therefore, increasing the transmitter output to the new FCC limit of 1500 watts will increase your signal by only about 3.8 dB, at a considerable expenditure in power amplifier cost.

Finally, there are the receiver considerations. The one most often discussed parameter is the noise figure. Usually, the lower the noise figure, the more sensitive the receiver, and the better you can hear the weak signals returning from the moon. However, on

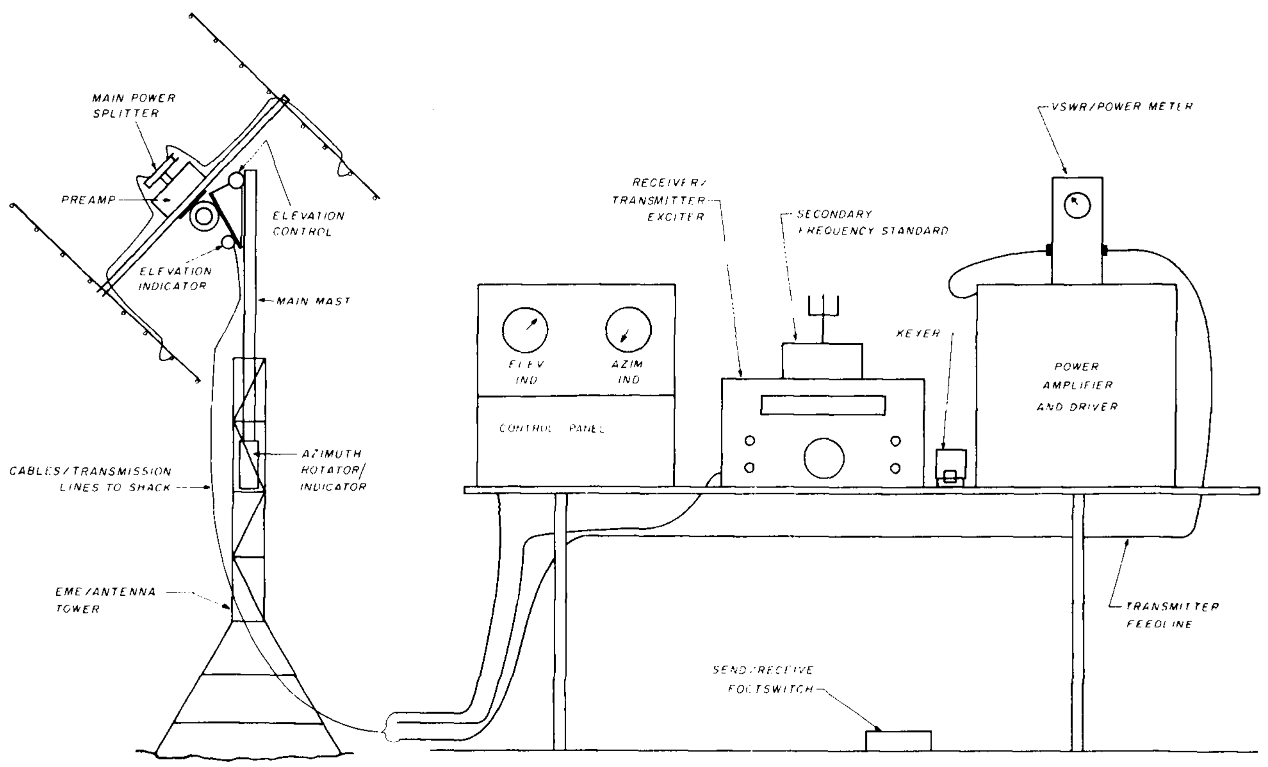

fig. 1. This figure shows the primary elements of a "minimum" 2-meter EME station as described in the text.

Table 1. This table shows the minimum requirements for successful 2-meter EME echoes as discussed in the text.

Path loss	252.5 ± 1 dB
Minimum antenna gain	20 dBi
Minimum transmitted power at antenna feed	500 watts (+ 57 dBm)
Maximum receiver noise figure referenced to the antenna feedpoint	1.5 dB
Receiver bandwidth	50 Hz

2-meter EME the law of diminishing returns applies. You're limited not only by the feed line loss in the antenna system, but by the noise the antenna "sees" as well (see reference 1). If your antenna feed line loss ahead of your preamplifier is low (i.e., 0.5 dB maximum), you probably won't gain much improvement by using a noise figure below 1.0 dB. This will be discussed below.

a marginal 2-meter EME station

By now you're probably wondering, "But what if I don't want to go all the way and build a minimum EME station? What are the *minimum* requirements?" All other parameters being equal, the only requirement that has to be satisfied is that the sum of the antenna gains at both stations be equal to or greater than 40 dBi. Therefore, if the other station has a 25-dBi antenna gain, you can have successful QSOs with only a 15-dBi antenna gain — the gain of a single high-performance Yagi on a boom measuring three wavelengths or longer.

If you have the minimum 20-dBi antenna gain and schedule a station sporting 25 dBi of gain, you can use power levels down to 5 dB lower, or as low as 150 watts at the antenna feedpoint! This explains why the "super stations" have been so successful; they have much greater gain than is required for the minimum station and usually have very low feed line losses, with very low-noise receivers with the preamplifier mounted at the antenna feedpoint. Running the maximum legal power of 1500 watts, they've obviously overcome the inadequacies of smaller stations.

Other EME tradeoffs are possible. Sometimes conditions are particularly favorable, especially if Faraday rotation cooperates, some scintillation enhancement is present, the moon is near perigee, and the sky temperature is low. Furthermore, as mentioned in last month's column, "ground gain," though elusive, can sometimes result in several dB of enhancement. This is particularly important to stations that don't have antenna elevation control (such as in a tropo setup) but want to try EME. Most of the super stations will be glad to accommodate any schedule requests.

EME antennas and antenna systems

Since the antenna system is the main key to EME success, it should be discussed first. Many antenna types — rhombics, collinears, parabolic dishes, and Yagi arrays — have been used successfully on 2-meter EME.

W3GKP and W4AO used rhombic antennas in the early 1950s to hear the first successful Amateur EME echoes, which were on 144 MHz.[1] Stacked rhombics were later used by VK3ATN and then by VK5MC. For the type of gains required, rhombics must be very large, typically 40 to 50 wavelengths, or 275-350 feet on a side! A rhombic antenna is therefore practical only in a fixed configuration for horizon shots in a narrow EME window. Rhombics also have many sidelobes, so they can't be considered low-noise receiving antennas.

Collinears, both standard and extended, were among the first really successful rotatable 2-meter EME antennas. They're not difficult to build or tune and usually have open wire phasing lines so losses are low and efficiency is high. Though collinears are large, some Amateurs were able to arrange them so they could be rotated not only in azimuth and elevation, but also in polarity; this option often makes the difference between success and failure.

Parabolic dishes such as the 1000-foot diameter reflector at Arecibo, Puerto Rico, and the 150-footer at Stanford, California, were used several times for 2-meter EME in the 1960s. However, parabolic dish type antennas aren't too efficient (typically only 50 to 55 percent), and really have to be at least 28 feet in diameter to be worthwhile for 2-meter EME. Despite their shortcomings, dish type antennas require only a simple feed system, they're usually low-noise on receive, loss to the receive preamplifier can be negligible, and they can be easily adapted to polarity rotation. Moreover, they can usually be operated on higher frequency bands if the the feed system is changed.

Table 2. This table shows some of the most common individual antennas presently used on 2-meter EME along with boomlength, number of elements, and estimated gain. The gains shown represent my best judgment and are based on tests and reported results at 144 MHz; they may vary ±0.25 dB.

name and/or manufacturer	boomlength in wavelengths	no. elements	gain dBd	gain dBi
W1JR short Yagi [9]	1.73	8	11.35	13.5
NBS Yagi	2.2	12	11.85	14.0
Cushcraft 214B Jr. Boomer Yagi	2.2	14	12.1	14.25
Cushcraft DX-120 collinear	na	20	12.5	14.65
Tonna (F9FT) 20116 Yagi	3.15	16	12.5	14.65
KLM 13LBA Yagi	3.2	13	12.5	14.65
CueDee Yagi	3.1	15	12.85	15.0
NBS Yagi	3.2	17	13.05	15.2
Tonna (F9FT) 20117 Yagi	3.15	17	13.15	15.3
Cushcraft 3219 Boomer Yagi	3.2	19	13.2	15.35
NBS Yagi	4.2	15	13.55	15.7
KLM 16LBX Yagi	4.1	16	14.15	16.30
Cushcraft 4218XL Yagi	4.2	18	14.3	16.45
KLM 17LBX Yagi	4.7	17	14.5	16.65
M² Enterprizes (K6MYC) 2M-5WL	4.8	18	14.5	16.65
28-foot dish	na	na	17.55	19.7
32-foot dish	na	na	18.65	20.8
40-foot dish	na	na	20.55	22.7

Nowadays, the Yagi is "king" on 2-meter EME. Over the last ten years Amateurs have expended a great deal of effort towards improving Yagi gain and decreasing sidelobe levels. The result is vastly improved arrays with as many as 32 separate Yagis — with no end in sight! Furthermore, Yagis pack a lot of gain based on volume and form factor. No wonder back yard EME is now so popular.

Table 2, which shows the gain of some of the most popular individual 2-meter EME antenna designs, can be used as a guide to antenna selection. It's interesting to note that the majority of the popular commercial Yagis presently in use on 2-meter EME are based on either the NBS or DL6WU Yagi designs. The gains shown on this table have been either measured or calculated using some of the latest computer modeling techniques and represent true gain.

Because long Yagi designs may be expensive to build — given the high cost of materials — many antennas used on 2-meter EME are commercial types. Homebrewed Yagis are still very popular, however, despite the cost. Both the NBS and DL6WU designs are highly recommended; reference 8 discusses the advantages and disadvantages of these and other Yagi designs.

If you want to start small, consider the simple eight-element Yagi design on a 12-foot boom described in reference 9. Four of these antennas stacked only 9 feet horizontally and 8 feet vertically will make an excellent compact, low-cost, back yard starter EME antenna just shy of the minimum gain in **table 1**. The array can later be expanded to six or eight of these Yagis if greater gain is desired.

stacking antennas

Because no practical 20-dBi gain Yagi designs are presently available for 2-meter EME (11 wavelengths, 70- to 80-foot boomlength!), one usually has to resort to stacking smaller antennas. **Table 3** shows the maximum gain possible if Yagi antennas are stacked, based on zero phasing line losses. Note that system gain doesn't increase 3 dB every time you double the number of antennas, even with zero phasing line loss! To do so would incur large sidelobes, which would severely increase the noise temperature of the antenna, making reception very diffi-

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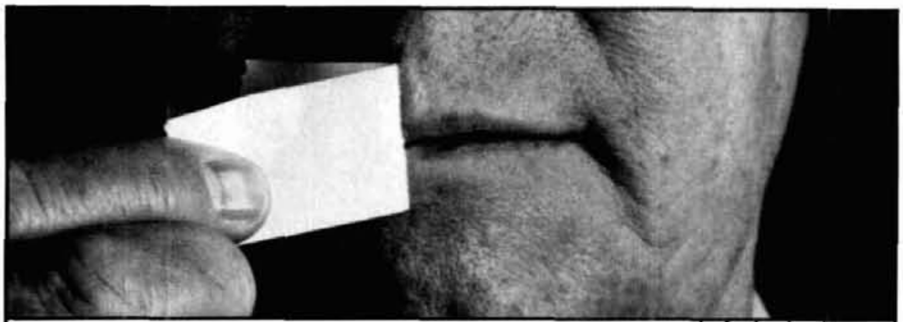

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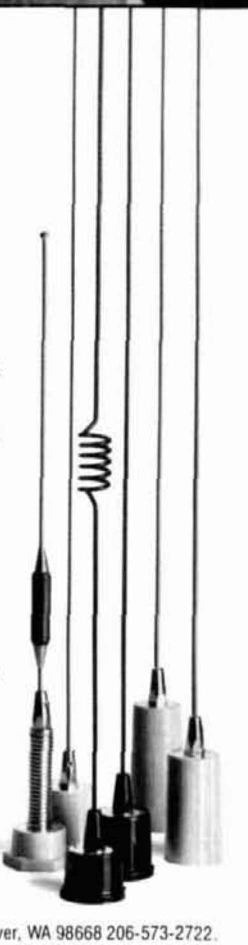

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Table 3. This table shows the typical stacking gain improvements for optimally stacked Yagi antennas, excluding any phasing line losses.

configuration	gain increase
2 antennas	2.75
4 Yagis	5.5
6 Yagis	7.1
8 Yagis	8.25
12 Yagis	9.85
16 Yagis	11.0
24 Yagis	12.6
32 Yagis	13.75

cult — especially on weak signals. Phasing line losses will decrease antenna performance accordingly. This is a big consideration when using four or more antennas.

Note in particular the stacking of six Yagis with only a two-times increase in size over four antennas for about 1.6-dB gain increase. This configuration is particularly recommended for Amateurs who just can't swing eight Yagis but need a little more antenna gain to stengthen their competitive edge.

The six-Yagi configuration is best accomplished by stacking them three high and two wide.[7] In the late 1970s, I built the power dividers and phasing lines for such a configuration and sent all the parts and information along with two extra antennas to Alaskan 2-meter EME station WA0LPK. Jim immediately installed the "kit" and went from 10-percent success on schedules to making contacts at random without schedules. While slightly more complex mechanically, this configuration has much to offer over going all the way to eight antennas with a three-times increase in size.

Table 4 shows examples of the gain of some of the more popular 2-meter EME Yagi antennas in typical stacking configurations. **Table 5** shows the estimated gain of some of the super stations. Many other configurations are available, but this should help.

Stacking antennas and using power splitter/combiners are discussed in detail in references 6 and 7, so that information won't be repeated here. First determine the gain of your single Yagi antenna; then you can estimate the gain improvement when they're stacked according to the information contained in **tables 3** through **5**.

Table 6 will help you determine the optimum spacing when stacking the antennas shown. Those not shown can be stacked using references 6 and 7 if the individual Yagi beamwidths and sidelobes are known. Don't get too worried about spacing — it isn't that critical, but if you must err, do so on the short side. Even a 10-percent shortening will decrease gain by only 0.25 dB and greatly decrease mechanical problems!

Table 4. This table shows some typical 2-meter EME arrays with estimated gains.

antenna and/or manufacturer	gain in dBd	gain in dBi
4 W1JR 8-el Yagis	16.85	19.0
4 Cushcraft 214B Jr. Boomers	17.60	19.75
4 16-el F9FT 20116 or KLM 13 LBA Yagis	18.00	20.15
80-el Cushcraft collinear	18.00	20.15
4 Cushcraft 3219 Yagis	18.70	20.85
4 KLM 16LBX Yagis	19.65	21.80
160-el Cushcraft collinear	20.75	22.90
6 KLM 16LBX Yagis	21.25	23.40
8 Cushcraft 3219 Yagis	21.45	23.60
8 KLM 16LBX Yagis	22.40	24.55

Table 5. This table shows the estimated antenna gain of some of the 2-meter EME "super stations."

antenna and/or manufacturer	gain in dBd	gain in dBi
K1WHS 24 Cushcraft 214B Yagis	24.7	26.85
WA6MGZ 16 KLM 16LBX Yagis	25.15	27.30
WA1JXN 16 KLM 17LBX Yagis	25.5	27.65
YU3WV 24 12-el J-Slots	26.0	28.15
KB8RQ 32 Cushcraft 3219 Yagis	26.95	29.10
W5UN 32 KLM 17LBX Yagis	28.25	30.40

transmission and phasing lines

Transmission line losses, even at 144 MHz, can be significant. This is especially true when long Yagis are used in large arrays where many phasing lines are required. Tradeoffs and different types of feed lines are discussed in detail in reference 10, so they won't be repeated here. Before you go too far in your antenna system plans, be sure to study the different types of transmission lines and learn how you can keep losses to a minimum.

If you can keep it well sealed from water penetration, type 9913 coax is highly recommended, especially for the phasing lines between the individual Yagis and the first power divider. Even RG 8 and 213-U coax types are usable in phasing lines if lengths are kept short. In this regard, the "back plane" configuration,[7] where the first power divider is mounted in close proximity to the feedpoint in the individual antennas, is particularly recommended .

Fifty-ohm Heliax® and hardline or Alumifoam® are highly recommended, especially for the transmitter feed line (**fig. 1**). While they're expensive, they can often be found at flea markets for reasonable prices. Especially in large arrays, very low-loss transmission lines need be used only on the long runs from the individual power dividers to the central antenna feedpoint.

Several 2-meter EMEers are using CATV hardline. (Ask super stations WA1JXN, K1WHS, and W5UN.) It's inexpensive and has very low loss, especially below 300 MHz, where it's closely specified by suppliers. Although it has an impedance of 75 ohms, it can easily be designed into the antenna system and later converted back to 50 ohms with a simple quarter-wave section of 61-ohm line.

Heretofore, it's been common Amateur practice to make phasing lines multiples of a half wavelength. This theory was debunked in reference 7. Since then, some Amateurs have tried using the odd number of quarter-wavelength techniques recommended

in reference 7 and have been quite pleased with the results. Lower sidelobes and higher gain were immediately evident because of the improved power distribution.

EME receivers and preamplifiers

Table 1 shows that a 2-meter EME receiver should have maximum a noise figure of 1.5 dB and a maximum bandwidth of 50 Hz. Earlier in this column, I briefly mentioned a receiver sensitivity of − 155.5 dBm. You're probably wondering how these parameters are related.

Receiver sensitivity is primarily a function of noise figure and bandwidth. If the antenna noise temperature is near room temperature (298 degrees K), the typical situation on 2-meter EME, the receiver sensitivity can be calculated using the equation shown below:

eqn. 3:

$$\text{Receiver sensitivity} = -174\ dBm + NF + 10 \log BW$$

where receiver sensitivity is in dBm, NF is noise figure in dB, and BW is bandwidth in Hz.

For example, if the receiver overall noise figure is 1.5 dB and the bandwidth is 50 Hz, the overall receiver sensitivity will be − 155.5 dBm (−174 + 1.5 + 10 log 50). But how do you get a bandwidth of 50 Hz as shown in **table 1** when your i-f bandwidth is 500 Hz? Use your ears! As the final link on the end of the receiver chain, the human ear has a typical bandwidth of only 50 Hz.[11]

If you're still not convinced, you can use a narrow i-f bandwidth. I've seen i-f filters advertised that claim a bandwidth of 125 Hz, but I'd hate to have to tune in a signal with such a narrow bandwidth — not to mention the frequency stability requirements of such a receiver!

If you don't have narrow i-f selectivity and you don't trust your ear, use an external audio filter. Some of the new solid-state active audio filters have variable bandwidth and frequency controls which will easily go down to audio bandwidths of less than 25 Hz.

Table 6. This table shows the recommended stacking distance for some of the more popular 2-meter Yagi antennas per reference 6 with updates.

antenna type	Stacking in E & H plane in wavelength		Stacking in E & H plane in inches	
W1JR short Yagi (ref. 9)	1.35	1.20	110	98
NBS 2.2 wavelength Yagi	1.55	1.40	127	115
Cushcraft 214B Jr. Boomer	1.55	1.40	127	115
Tonna (F9FT) 20116 Yagi	1.60	1.50	131	123
KLM 13LBA Yagi	1.80	1.55	147	127
CueDee Yagi	1.70	1.40	139	115
NBS 3.2 wavelength Yagi	1.80	1.35	147	111
Tonna (F9FT) 20117 Yagi	1.55	1.40	127	115
Cushcraft 3219 Boomer Yagi	1.80	1.35	147	111
NBS 4.2 wavelength Yagi	1.95	1.75	160	144
KLM 16LBX Yagi	2.00	1.75	164	144
Cushcraft 4218XL Yagi	1.95	1.75	160	144
M² Enterprizes 2M-5WL Yagi	1.95	1.80	162	147

The one major difference between a conventional VHF/UHF or hf receiver and an EME receiver lies in the external preamplifier that's usually mounted at or very close to the antenna feedpoint. This is almost always necessary for two reasons. The first is that the line loss to the shack is usually over 0.5 dB, so the weak signal is further attenuated. The second is that there are no conventional receivers with 1- to 1.5-dB overall noise figures as required in **table 1**.

First a word about preamplifiers. There are many options. Although I used only a U-310 JFET preamplifier (shack-mounted at that) to obtain my 2-meter WAS Award, I now recommend the use of a GaAsFET preamplifier mounted in a small enclosure as close to the antenna feedpoint as possible. Many preamplifier circuits — as well as commercially manufactured units — are available.

However, one mustn't get carried away with specifications. For instance, there's practically no justification for 2-meter EME preamplifier gains in excess of 25 dB; even 20 dB may be overkill. Very often I see 144-MHz GaAsFET circuits using tuned output stages. When this is done below about 1000 MHz, the circuit is almost always on the verge of oscillation. This can result in an input impedance off the Smith chart when a preamplifier is measured on a network analyzer. Instability is also evident if a preamplifier oscillates when placed in the antenna system where the impedance is not constant at all frequencies! Furthermore, excessive preamplifier gain may cause your receiver to intermodulate because of the presence of other Amateurs, fm repeaters, or even commercial fm and TV signals that often pass through the preamplifier.

At 144 MHz, I prefer GaAsFET preamplifiers with tuned input tanks and untuned outputs such as those that use a 4:1 broadband output transformer. Some recommended GaAsFET preamplifier circuits are described in reference 12. If you have any doubt about preamplifier stability, measure the forward gain and reverse isolation with a very weak signal source. If the reverse isolation isn't at least 4 to 6 dB higher than the forward gain, the preamplifier is potentially unstable.

If you use an external low-noise preamplifier as recommended above, and mount it at the antenna feedpoint, the loss and type of the transmission line between the preamplifier and the receiver usually isn't critical, since the overall gain of the preamplifier is typically 20 to 25 dB. Hence moderately lossy coax cable such as RG-8 or RG-231/U is perfectly acceptable (see **fig. 1**).

Two-meter EME receivers offer many options. A decade ago most 2-meter EMEers used a downconverter or transverter followed by an hf receiver for the i-f. This setup has lots of system flexibility.

When choosing an hf i-f for EME operation, look for a receiver that has good frequency stability, a slow tuning rate (25 or less kHz per turn), frequency readout that has good resolution and accuracy, narrow bandwidth i-f options, an SSB/CW product detector, and an automatic noise blanker. An i-f bandwidth of 250 to 500 Hz is recommended, as discussed above. Some of the favorite EME i-f receivers of yesteryear were the old Collins 75A4 and the Drake R4C with appropriate modifications. More recently, the Kenwood TS 830 and TS 430 have become popular.

Many multimode 2-meter transceivers are available. Until recently, the Yaesu FT-726R was a favorite because of its built-in narrow bandwidth CW filter. Other 2-meter transceivers now offer this option. You can use a transceiver with a 2- to 3-kHz i-f bandwidth if your ears don't mind all the excess noise; better yet, follow the transceiver with an external audio filter as mentioned previously. This is the setup at one of the 2-meter super stations!

transmitters and power amplifiers

If you have either a 2-meter transverter, upconverter, or one of the new multimode transceivers, you have the basic building block for a 2-meter EME exciter. Frequency stability is important. Remember that the station trying to work you may be listening in a 50- to 100-Hz bandwidth, so any chirp or drift on your part will significantly degrade success.

Probably the biggest choice lies in deciding how to generate power. If you build a marginal station and expect to work only the super stations, a typical beginner's approach, a solid-state "brick" will probably be sufficient. Many circuits can be found in reference 13; commercial solid-state amplifiers are also available.

However, always build or buy one of the linear amplifier types. You may later use this amplifier as a driver for a high-power final. Class C or fm amplifier types often exhibit erratic power output levels when their drive levels are varied. This could make output power setting very difficult or damage a follow-up final amplifier.

There are many choices of high-power amplifiers. Remember that even 500 to 750 watts of output power is sufficient for operating 2-meter EME. There are still plenty of plumbers' delights or parallel tube finals around — especially those that use the venerable 4CX250Bs. Often available quite inexpensively, especially from Amateurs who are upgrading to the new FCC 1500-watt output power levels, they'll easily generate as much as 1000 watts of output if they're properly cooled. More information on these finals is contained in references 14 and 15. The 8874 and 3CX800A7 tubes have become popular, especially where single-tube amplifiers are preferred. Other tubes such as the 7650, 7213, and 4CX1000 are usable. Other finals are described in references 16 and 17. The most popular 2-meter EME final for generating the full legal limit is the W6PO power amplifier, which uses an 8877.[17, 18] This amplifier has excellent stability, and is conservatively rated and reasonably efficient (i.e., greater than 60 percent). Furthermore, individual components, parts kits, or even a completed amplifier using this circuit are now available.* Finally, several commercially manufactured tube type finals are now available for 2-meter operation.

azimuth and elevation rotators

Any detailed discussion of this subject would require an entire article of its own. Some of the systems presently in use on 2-meter EME range from simple single Yagis on a tropo setup to complex arrays with exotic rotating systems occupying an entire acre of land.[19] Most EMEers will simply use their own ingenuity, building a rotator according to the requirements of the station and the materials most easily pressed into service.

Reference 9 showed my simple back yard/portable array, resting on a small, ground-mounted 11-foot tower for the base. A conventional Ham-M or equivalent rotator is used for azimuth control. Elevation is set by a small boat winch mounted on the vertical mast just above a hinged plate that holds the horizontal boom. Elevation angles are measured with a hand-calibrated plate and lead weight attached to the main boom. This setup is simple and relatively inexpensive.

Several large commercial rotators are now available with accuracies approaching 1.0 degree. While separate selsyn indicators used to be common, auxiliary azimuth indicators that use a linear potentiometer are becoming quite popular now that low-cost digital voltmeters are available.

Some Europeans have cascaded two or more of the elevation rotators used for typical OSCAR antenna control. For large antenna systems, the venerable "prop pitch" motor is still alive and well. Several years ago, many different EME rotator systems were described in Eimac's *EME Notes*.[20]

polarity rotation

So far I've only touched on the subject of polarity rotation. Circular polarization would greatly improve the Faraday rotation problem on 2-meter EME, but it's very difficult to implement on large Yagi arrays. As mentioned before, circular polarization would reduce the signal levels from linearily polarized stations by up to 3 dB.

For these reasons, some Amateurs have devised polarity rotation schemes for collinears (VE7BQH) and Yagi arrays (K5GW), but describing them in detail would require discussion of mechanical considerations beyond the scope of this column. In this regard, the parabolic dish has much to offer despite its low efficiency and size. The rest of us will just have to trust our luck to the Faraday rotation present during our schedules!

---

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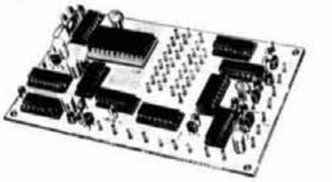

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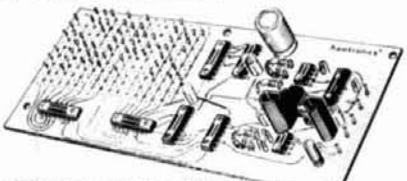

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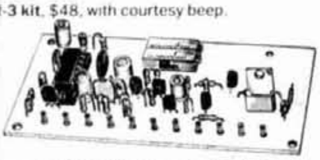

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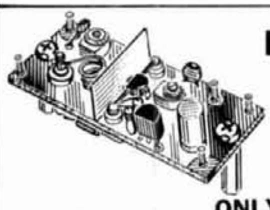

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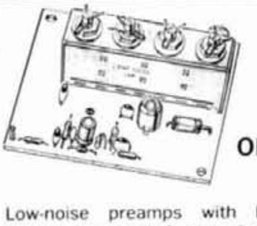

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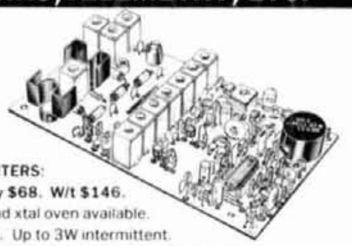

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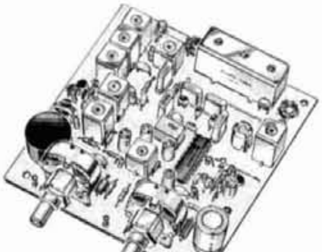

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	144-146	50-52
	144-146	28-30
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relays and control systems

The simplicity or complexity of this part of the system is a matter of personal choice. **Figure 1** shows most of the components required for a complete minimum station. Rotator cables and the like are quite straightforward.

The one area that deserves some special consideration is the antenna changeover and receiver protection relays. There are two major problems with these in EME operation. The first is the leakage or isolation of the main T/R relay. When running over 500 watts of output power, the leakage across this relay when in transmit can be sufficient to burn out your receiver preamplifier unless the isolation is greater than 50 dB. Many of the T/R relays used by Amateurs offer marginal isolation at 144 MHz. Second, the switching time on the T/R relay is critical because if the high power is applied before the relay is fully transferred, the preamplifier is again subjected to rf burnout levels.

Most of these problems can be solved if you have a short built-in time delay before rf or high voltage is applied to your final power amplifier. Additional isolation in the form of a second relay in series with the preamplifier is also recommended. This relay can be a low-power type and preferably will terminate the preamplifier input, with a 50-ohm load during transmit. If the length of the coax between the relays is 0.1 to 0.25 wavelength, it will increase isolation.[3]

These features should be wired into the station control system, with a foot switch to further control the sequences of events. Therefore, I recommend that you review the scheme and schematic of the recommended switching technique described in reference 3.

system checkout

Before you try to fire up and listen for EME signals, it's best to make sure that your system is functioning properly. If it's convenient, disconnect the preamplifier and test the antenna system for VSWR. If everything was properly installed, the VSWR should be well below 1.5:1. Then increase your power to confirm that there's no output power problem.

Next, reconnect your preamplifier and receive system. Check your receive system by pointing your antenna towards different areas of the sky. The noise level should vary as you point to radio "hot spots." Aiming your antenna at the sun — the largest hot spot — should increase the noise output of your receiver by at least 6 to 8 dB.

After peaking your receiver on the sun, sight up the antennas and verify that the sun is reasonably close to boresite. Next point your antenna away from the sun and try to measure your first sidelobes, which should be detectable but many dB below the main beam. If the sidelobes are high or the antenna doesn't boresite well, check your phasing lines for possible phase inversions.

Now try some echo testing. Send a letter or two and listen carefully for an echo. Remember that the returned signal may be up to 500 Hz above or below the transmitted signal, depending on whether the moon is approaching or leaving you, as described in reference 1. If you don't hear anything, don't be discouraged. Faraday may be unfavorable. Try again in 15 to 30 minutes.

Next listen for other EME signals. There's almost always activity on weekends and evenings whenever the moon is above the horizon at north declination. Tune between 144.000 and 144.020 and see if you find any EME signals; this is where most of the super stations congregate and where most random CQs take place.

If you don't hear any signals, activity may be low or Faraday rotation may be unfavorable. Wait a while and try again. Check the 144-MHz EME Directory for someone you can contact locally.[21] Better yet, set up a schedule with one of the active EME stations, who can usually be found on 14.345 MHz on Saturdays and Sundays between 17 and 1900 UTC on the 2-meter EME net usually MC'ed by Lionel, VE7BQH.

scheduling

This is a subject in itself which is again beyond the scope of this month's column. Many scheduling tips and recommendations can be found in references 1 and 22. Try to make schedules near perigee, when the moon is at northerly declinations away from the galactic plane, and when there are no local objects obstructing the antenna view. Perigees are always listed at the end of each month's column, and an EME calendar appears monthly in *VHF/UHF and Above.** Unless there are no other possibilities, don't make schedules when the moon is in the galactic plane, at the new moon phase, or when the moon is at low elevation angles (except for horizon shots where there may be no other possibilities).

When you run a schedule, it's best to follow the standard techniques and scheduling sequences that have become well established procedures. First, the scheduled frequency is your zero beat frequency. Since doppler is usually present, leave your transmitting frequency fixed and tune only your receiver until you find the desired station.

Most schedules conducted on 2-meter EME are for either one-half or one hour's duration. Each station usually transmits and receives alternately for two minutes at a time. The easternmost station generally transmits during the first two-minute period at the start of the hour. This is often referred to as "standard sequencing."

For example, if a W2 station schedules a W6 station between 1900 and 2000 UTC, the W2 station, as the eastern station, would transmit from 1900 to 1902 UTC and listen from 1902 to 1904 UTC, and so forth. If, however, the schedule is from 1930 to 2030, the W6 station would transmit first from 1930 to 1932, since sequencing is based on the hour, and with 2-minute sequencing, there are an odd number of periods in the first half of the hour.

---

*Rusty Landes, KA0HPK, "VHF/UHF and Above Information Exchange," P.O. Box 270, W. Terre Haute, Indiana 47885.

The reporting system used on 2-meter EME is different from the one used on 432 MHz and above. "T" designates detectable signals, "M" means letters or portions of calls, and "O" verifies that both call signs have been copied. Therefore, an exchange of an "O" report and appropriate "Rs" are required for a valid QSO. Never transmit an "O" report or an "R" until you have complete call sets and reports respectively, because the reporting sequence can only go forward!

Most 2-meter operators make up a standard schedule sheet with each 2-minute time block designated. They then write in all information sent and received in the appropriate time blocks; this will help if there are deep fades or partial copy, Faraday rotation problems, or if authentication is required later on.

other tips

Have someone in your area check your frequency to confirm that you're transmitting where you think you are. A secondary frequency standard such as the one described in reference 23 is recommended. Use the 2-meter EME net to make schedules or to see who's active, when they're active, and what frequency they're on. *The 144-MHz EME Directory*[21] is a *must* if you want to know what other stations are active and what equipment they use. Published monthly, *The 2-Meter EME Bulletin* includes good tips and information about the activity of other 2-meter EME stations.*

summary

So there you have it — all the necessary basic information needed to get you started on 2-meter EME. Let me know if I missed any necessary information. Some of the topics discussed had to be dealt with only briefly, but the references cited or the EME nets are excellent sources for further details or clarification. As is often the case, it sometimes takes longer to explain a

*Gene Shea, KB7Q, "2-Meter EME Bulletin," 417 Staudaher Street, Bozeman, Montana 59715.

particular item in print than to demonstrate it in a hands-on situation.

If you have only a small antenna, consider listening for EME signals in the 144.000-144.020 MHz region, especially during the EME contest on October 17-18 and November 14-15, 1987. Even if you're not ready to get started in EME, try putting up a simple antenna in your back yard and see what you can hear. Who knows — the bug might bite! See you on EME shortly!

new records

In Oregon on March 8, 1987 at 1950 UTC, Tom Hill, WA3RMX/7 (CN85PL), and Lynn Hurd, WB7UNU (CN85NH) did it again by breaking their own North American DX record on 47.040 GHz. This time they extended the distance to almost 14 miles, and again had a two-way QSO on SSB with good signal-to-noise ratios. Tom was running 3.5 milliwatts to a 28.5-inch dish, while Lynn was running just 44 microwatts to a 9.5-inch dish!

Meanwhile, as predicted in last month's column, new EME records were being made. On April 12, 1987 at 0530 UTC, Lucky Whitaker, W7CNK/5, Oklahoma City, Oklahoma (EM15FI), worked Keith Ericson, K0KE, who was operating portable in Denver, Colorado (DM79NO), on 3456.1-MHz EME for a new worldwide EME DX record of 498 miles. Lucky was using a 5-meter dish and 80 watts, while Keith borrowed the use of a 10-meter satellite dish and was running only 12 watts of output power! Signals were copied easily off a speaker with a 2.5-kHz receiver bandwidth!

Not content with this record, Lucky, W7CNK/5 (EM15FI), converted his setup to 5760.1 MHz. Then he completed the first Amateur two-way EME contact on that band on April 24, 1987 at 1620 UTC with Rick Fogle, WA5TNY, Grapevine, Texas (EM12KV), for a 174-mile record. Lucky was running 100 watts to his 5-meter dish and Rick was running only 25 watts to a 10-foot TVRO dish. After the initial contact, Dave Hallidy, KD5RO, jumped in, using Rick's station to give

W7CNK/5 his second 5760.1-MHz contact.

Congratulations to Tom, Lynn, Lucky, Keith, Rick, and Dave. The spring of 1987 may go down in history as one of the greatest record-breaking periods in UHF/SHF history.

important VHF/UHF events

September 5-6	International Region 1 VHF Contest, 2 meters only
September 6	EME perigee
September 10-13	Microwave Update 1987 Conference, Estes Park, Colorado (contact W0PW)
September 12-14	ARRL September VHF QSO Party
September 19-20	ARRL 10-GHz Cumulative Contest, second weekend
September 21	±2 weeks. Optimum time for TE propagation
October 3-4	International Region 1 UHF/SHF Contest, 70 cm and up
October 4	EME Perigee
October 9	Predicted peak of the Draconids meteor shower at 0900 UTC
October 10-11	Mid-Atlantic States VHF Conference, Warminster, Pennsylvania (contact WA2OMY)
October 17-18	ARRL EME Contest, first weekend
October 21	Predicted peak of the Orionids meteor shower at 0830 UTC
October 30	EME Perigee

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18. Robert I. Sutherland, W6UOV, "High Performance 144-MHz Power Amplifier," *ham radio*, August, 1971, page 22.
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22. Joseph H. Reisert, W6FZJ/1, "EME Scheduling, When and Where," *QST*, July, 1974, page 25.
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short circuits

spacing dimensions

In **fig. 2** of W1JR's April, 1987, column (page 74), the spacing dimensions listed for the fourth director, D4, of the 46-element loop Yagi do not agree with the drawing. The drawing is correct; the listing should be corrected to show the spacing for D4 as 14.1721 (TNX K5DUT).

In **fig. 6**, the length of the inductors is not shown because it is assumed that the specified enclosure will be used. If it is not used, the height of the inductor above ground should be about 1.5 inches.

pin 16, not 10

In **fig. 6** of W1JR's June, 1987, column (page 75), pin 10 on the left-hand side of U1 (between pins 12 and 13) should have been labeled as pin 16 (TNX W5YHT).

missing table

Table 1, omitted from W1JR's VHF/UHF World column in the April issue (page 55), is shown below.

Table 1. Some citizens-band type fm transceivers are available in Japan but not yet in the USA.

Company	Part No.	Price
ICOM	GTX	NA
Shinwa	SC-905GII	NA
Yaesu	FYA903	NA
Yaesu	FYA905A	approx. 80,000 Yen

220 Notes

In table 5 of W1JR's July, 1987 column (page 38), *220 Notes* was indicated as being issued quarterly. This is incorrect; *220 Notes* is published bimonthly. To subscribe ($5/year), contact Walt Altus, WD9GCR, 215 Villa Road, Streamwood, Illinois 60103.

20-meter travelradio

Planning to build K1BQT's compact CW transceiver (June, 1987)? Send an SASE (with 39 cents postage) to *ham radio*, Greenville, NH 03048, for a complete list of corrections.

the ham notebook

improving the WB3CEH programmable call sign identifier

When Gene Colson, KL7YM, was constructing a new repeater for our mountain top site in Fairbanks, WB3CEH's article describing his programmable call sign identifier[1] caught my eye. The identifier appeared to be perfect for our needs. But when I began ordering the parts, I couldn't find the MC14557 64-bit shift register IC specified, and neither KL7YM/R, WB3CEH (the author's call), nor KL7XO (my own call) would fit into 64 bits.

A search through catalogs revealed a substitute for the MC14557: the CD4031, also a 64-bit shift register. A phone call to Jameco* brought several of them within a week. I cascaded two for a total of 128 bits and reversed the A and B inputs to reduce standby power consumption.

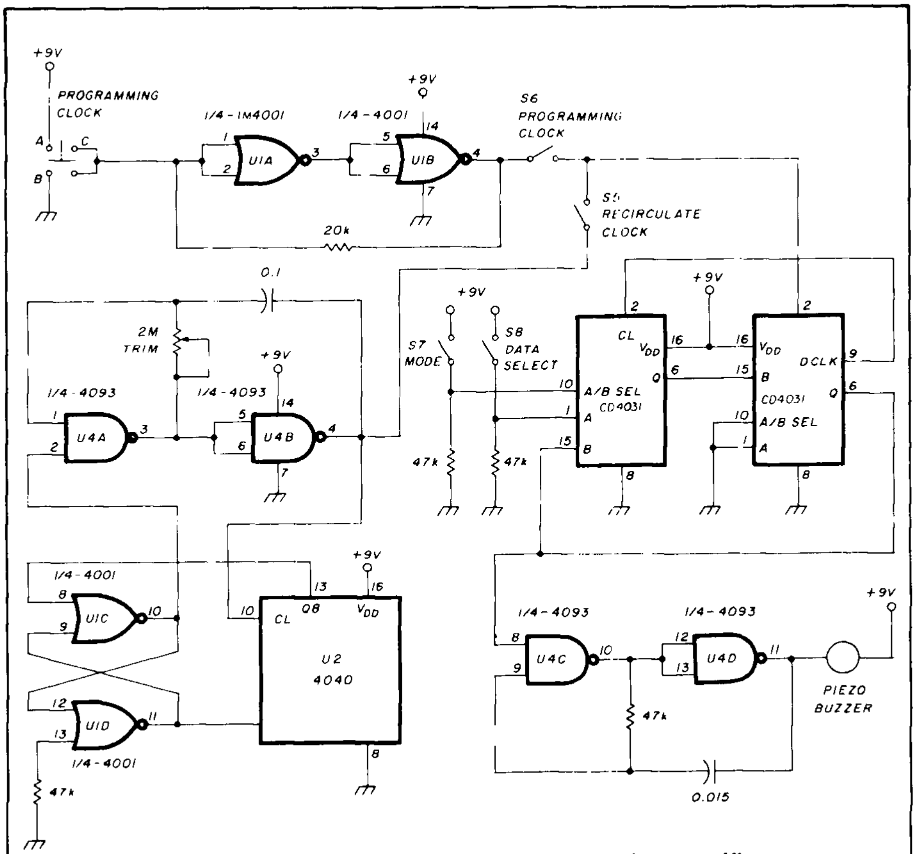

fig. 1. Modified WB3CEH programmable call sign identifier.

I built the first one. It worked, with measured current consumption of 0.0005 mA on standby, 0.17 mA running without the buzzer, and 0.55 mA with the buzzer. Over two years later, it's still on the bench in my shack — with the original 9-volt battery. KL7YM built the production model, which is still in use on the repeater.

The construction and programming instructions in the original article still apply. The schematic of the modified circuit is shown in **fig. 1**.

Steve Estes, KL7XO

reference

1. Donald G. Varner, WB3CEH, "Programmable Call Sign Identifier," *ham radio*, February, 1985, page 33.

*Jameco, 1355 Shoreway Road, Belmont, California 94002.

carpet samples in the ham shack

While shopping for new carpet several years ago, I stumbled upon a pile of 18 by 24-inch samples with nicely finished borders being sold for a dollar each. I bought several.

What does this have to do with Amateur Radio? Well, one sits on my workbench to protect the surface from scratches and wear. It also protects radios from scratches and dings while I'm working on them. I selected a tightly woven, light-colored pattern for this so that small screws and parts wouldn't disappear. Another sample ended up beneath my very large, heavy Qume Sprint 5 daisy-wheel printer, helping to silence its operation. Another found its home under a fairly large hf linear amp.

When you have to move something heavy (like an overstuffed filing cabinet) across hardwood or linoleum floors, try sliding two or more of these carpet samples face-down under the object; it will then slide easily across the floor without scratching.

Most carpet shops sell these samples quite reasonably. Pick up a few and see how many uses you can find for them!

Peter Bertini, K1ZJH

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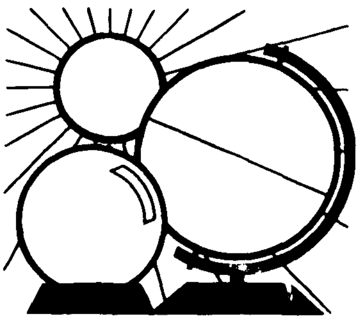

DX FORECASTER

Garth Stonehocker, KØRYW

more sporadic E

Before the Sporadic E (E_s) propagation season — June through September — is over, the results of some recent experiments are worth mentioning.

An ionosonde is a low-frequency, mf-hf radar that provides information about ionospheric layers by transmitting a signal vertically and measuring the duration of its round trip.* Using an ionosonde located in Hawaii, researchers have been able to identify and measure E_s cloud formation and movement, determining the east-west, north-south, and height changes of the signal's reflection point by means of doppler frequency shift data.

At altitudes below approximately 72 miles, there's a neutral particle "sandwich"; its upper level moves in a westerly direction, while its lower level travels in the opposite direction. Collisions between the particles in these layers and gyromagnetic interaction result in vertical ion movement from below and above the region. Very thin, intense, long-lived layers develop at the specific height at which the net ion vertical velocity is zero.

These metallic ions are of meteoric origin; it is the variations in their content that accounts for E_s patch differences, locations, and diurnal behavior. These differences — in turn manifested by varying layer shape (gradient), thickness, and intensity — account for changes in the maximum frequency that can be reflected.

For a clearer idea of the magnitude of these variations, consider this: over a period of only 20 minutes, the maximum usable frequency changed from 4 to 8 MHz in a patch that was only 6 miles long. Such clouds, however, can cover areas as large as 36,000 square miles (60 × 600 miles) and last up to 2 hours, resulting in long 10- or 15-meter openings.

last-minute forecast

During the first week and the ten days of September, expect low values of flux, resulting in the lower frequency bands being best. Nighttime openings will occur on these bands on the east-west and northern paths. If the geomagnetic field is disturbed on September 1st through 4th and 24th through the 29th, expect lower signal strengths and QSB. The second and third weeks are expected to offer very good higher hf-band DX openings in southerly directions. Some of the openings may be the result of transequatorial propagation, particularly in the evening and during disturbed conditions.

The moon will be full on September 7th and at perigee on the 6th. The autumnal equinox will occur on the 23rd at 1345 UTC. No significant meteor showers are expected this month.

band-by-band summary

Six meters may have a few E_s openings around local noon, but don't count on them during this last month of the season.

Ten, twelve, and fifteen meters should provide a few short-skip openings and many long-skip openings to most southern areas of the world, especially if there is any solar flux increase during the daylight hours this month. Some of these openings will result from transequatorial propagation, mainly during disturbed conditions.

Twenty, thirty, and forty meters will support propagation from the eastern, western, and northern areas of the world during daytime and on into the evening hours almost every day. Distances to 2000 miles via long-skip or some short-skip E_s to 1000 miles per hop are usual.

Thirty, forty, eighty, and one-sixty meters are all good for nighttime DX. The bands will be open in the east soon after sundown, swing toward the north and south about midnight, and end in the Pacific areas during the hour or so before dawn. The time-and-frequency stations in England and Hawaii make good band monitors. On some nights these bands will be as good as they are during the winter DX season; on others, QRN may be a problem. Distances will be a little shorter than those mentioned above.

---

*Other *analog* ionosondes transmit signals obliquely and work in pairs; more advanced *digital* ionosondes generate phase and polarization information in addition to the standard amplitude data. — Ed.

SEPTEMBER

WESTERN USA

	2300	2200	2100	2000	1900	1800	1700	1600	1500	1400	1300	1200	1100	1000	0900	0800	0700	0600	0500	0400	0300	0200	0100	0000	GMT
	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	6:00	5:00	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	6:00	5:00	PDT
ASIA FAR EAST	20	40	*40*	*40*	*40*	*40*	*40*	40	40	30	30	*40*	*40*	*40*	*40*	40	40	40	30	20	20	20	20	20	N
EUROPE	40	30	20	20	20	20	20	20	20	20	20	20	30	*40*	*40*	*40*	*40*	40	40	*40*	*40*	*40*	*40*	40	NE
S. AFRICA	20	15	15	15	15	12	12	12	12	15	15	15	*20*	*30*	*30*	*20*	20	20	20	*20*	*20*	*20*	20	20	E
S. AMERICA	12	12	10	10	12	12	12	15	15	15	20	*20*	*20*	*20*	*20*	*20*	*20*	*20*	20	20	15	15	15	15	SE
ANTARCTICA	15	15	15	15	15	15	20	20	20	*40*	*40*	*40**	*30*	*30*	*30*	30	30	30	20	20	15	15	15	15	S
NEW ZEALAND	12	15	15	15	15	20	20	*30*	*30*	*30*	*20*	*20*	*20*	20	20	20	15	15	15	12	12	12	12	12	SW
OCEANIA AUSTRALIA	12	15	15	15	20	*30*	*20*	*20*	20	*30*	*20*	*20*	20	20	20	20	15	15	15	12	12	10	10	12	W
JAPAN	15	20	20	20	20	20	*40*	*40*	*40*	*40*	*40*	*40*	*40*	*40*	40	30	30	30	30	20	20	20	20	15	NW

MID USA

	2300	2200	2100	2000	1900	1800	1700	1600	1500	1400	1300	1200	1100	1000	0900	0800	0700	0600	0500	0400	0300	0200	0100	0000	GMT
	5:00	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	6:00	5:00	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	6:00	MDT
ASIA FAR EAST	20	30	*40*	*40*	*40*	*40*	40	30	30	20	20	20	*40*	*40*	*40*	*40*	40	40	40	30	30	20	20	20	N
EUROPE	40	30	20	20	20	20	20	20	20	20	20	20	20	30	*40*	*40*	*40*	*40*	*40*	*40*	*40*	40	40	40	NE
S. AFRICA	20	15	15	15	15	12	12	12	12	12	15	15	15	20	*30*	*30*	*20*	20	20	*20*	*20*	*20*	20	20	E
S. AMERICA	12	12	12	12	12	12	15	15	15	15	15	20	*20*	*20*	*20*	*20*	*20*	*20*	20	20	15	15	15	15	SE
ANTARCTICA	15	15	15	15	15	15	15	20	20	20	*40*	*40*	*40*	*30*	*30*	*30*	30	20	20	20	20	15	15	15	S
NEW ZEALAND	12	12	15	15	15	15	20	20	*30*	*30*	*30*	*20*	*20*	*20*	20	20	20	20	15	15	15	12	12	12	SW
OCEANIA AUSTRALIA	12	15	15	15	20	*30*	*20*	20	20	20	*30*	*30*	*20*	20	20	20	20	15	15	12	12	12	10	12	W
JAPAN	20	20	20	20	20	20	*40*	*40*	*40*	40	30	30	*40*	*40*	*40*	*40*	40	30	30	30	20	20	20	15	NW
	6:00	5:00	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	6:00	5:00	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	CDT

EASTERN USA

	2300	2200	2100	2000	1900	1800	1700	1600	1500	1400	1300	1200	1100	1000	0900	0800	0700	0600	0500	0400	0300	0200	0100	0000	GMT
	7:00	6:00	5:00	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	6:00	5:00	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	EDT
ASIA FAR EAST	30	*40*	*40*	*40*	*40*	40	40	40	30	20	20	20	20	20	20	*40*	*40*	*40*	*40*	40	40	40	30	30	N
EUROPE	40	40	30	20	20	20	20	20	20	20	20	20	20	20	20	30	*40*	*40*	*40*	*40*	*40*	*40*	*40*	*40*	NE
S. AFRICA	20	15	15	15	15	12	12	12	12	12	12	15	15	15	20	*30*	*20*	20	20	*20*	*20*	*20*	20	20	E
CARIBBEAN S. AMERICA	12	12	12	12	12	12	15	15	15	15	15	15	20	*20*	*20*	*20*	*20*	*20*	20	20	15	15	15	15	SE
ANTARCTICA	15	15	15	15	15	15	15	20	20	20	*40*	*40*	*40*	*40*	*30*	*30*	*30*	*30*	30	20	20	20	15	15	S
NEW ZEALAND	12	12	15	15	15	20	20	*30*	*30*	*20*	20	20	*30*	*30*	*20*	20	20	20	20	15	15	15	15	12	SW
OCEANIA AUSTRALIA	12	12	15	15	20	*20*	*30*	*20*	20	20	20	20	*30*	*30*	*20*	20	20	20	20	15	15	15	12	12	W
JAPAN	20	20	20	20	20	40*	*40*	*40*	*40*	*40*	40	40	30	30	*40*	*40*	*40*	*40*	40	40	40	30	20	20	NW

The italicized numbers signify the bands to try during the transition and early morning hours, while the standard type provides MUF during "normal" hours.

*Look at next **higher** band for possible openings.

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Kenwood TH205AT	Trade in your old HT
Kenwood TS 440S/AT	Call for trade
Icom R7000 25-2000 MHz	949.00
Icom IC735	849.00
KDK FM 340, 220 MHz, 25w	319.00
KDK FM 240 NT	279.00
Mirage Amps	15% OFF
Tokyo Hy-Power HL 1K AMP, no 4CX250B	699.00
New Kenwood TM-221A, 45W, mobile	Call
VJ Amplifier, VHF, built in England, 1 in-100 out, 3-100, 5-100	(ea.) 249.00
10 in-100 out	229.00
25 in-160 out	319.00
All models include preamp	
Lunar 2M4-40P	109.00
Yaesu FT-727 RH, new CPU	Call
Kenwood TW-4100A	Call

ACCESSORIES

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Heil HC4/HC5	Stock
Heil BM10 Boom Mike headset	CALL
Tri-H 5000A Remote Phone	$189.00
Daiwa NS660A 30/300/3000 watts	135.00
Alinco ELH 230D- Excellent buy	88.00
Nye MB5-A (for the big boys!)	529.00
Shure 444D	54.95
Ameco PT-3	Soon
New Tokyo HC 200A	115.00
Astatic SilverEagle & Base	66.00
Ten-Tec Mobile Switch 3001	17.00

ANTENNAS

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Isopole 440 MHz	59.95
Cushcraft 124-WB (146 MHz)	33.00
Butternut HF6V, 80-10 vertical	125.00
HF2V, 80 & 40 vertical	119.00
HF4B	189.00
Hustler G7-144	119.95
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OTHER ANTENNAS

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Avanti AP151.3G on Glass Antenna	36.00
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Van Gordon ND-4, 4 band Novice dipole	45.00
Valor AB-5 Mobile	79.95
Stoner DA100 D Active Rx Antenna	190.00
DC 'Tenna Hitch 3/8-24 Thread Fits 3/4" trailer hitches	29.95

PARTS

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2.5A/1000PIV Epoxy diode	29 each or 19.00/100
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365pF cap	1.95
Sanyo AAA,AA Nicads w/tabs	2.00
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1/8, 1/4, watt carbon resistors	.05 each
Meter 0-3000 VDC 0-1 Amp DC 2½" Square with shunt	19.95
Drake—Collins mike plug	2.00
Thousands of panel meters	3.95 up CALL
MICA Cap .0004/3KV	5.00 others CALL
Diodes 3A/1000 PIV	.29
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3/16" Guy Cable. 3700 #7 × 7 strand, import	15c/ft.
3/8" × 6 E&J Turnbuckle	7.95
3/16" Wire Rope Clips	.40
1/4" wire clips	.50
1/4 Thimbles	.45
Porcelain 500D Guy Insulator (3/16)	1.99
Porcelain 502 Guy Insulators (1/4)	3.39

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REVIEW

Cushcraft 2-meter boomer

In 1979 Cushcraft introduced its 2-meter "Boomer"™ line of antennas, thus launching a new generation of long-boom, high-performance Yagis. A few years later, in response to a growing need for a 2-meter Yagi with even higher gain and a cleaner radiation pattern, Cushcraft introduced its new 2-meter Boomer 4218 XL Yagi.

This antenna is basically an enhanced NBS type Yagi. The trigon reflector, a "trademark" of the Boomer Antennas, improves the gain slightly but primarily enhances the front-to-back ratio. An extra director has been added between the driven element and the original first director for extra gain.[1] Cushcraft engineers found they could also improve gain and radiation pattern even more by moving the position of the original first director and extending all director lengths to compensate for errors in the original NBS designs.

The "T" match and half-wave balun used are other Boomer trademarks. Cushcraft retains the UHF connectors, which are not waterproofed, but supplies silicon grease and vinyl connector boots to keep the balun and feed line connectors relatively waterproof. I'd still prefer the use of type N connectors.

This antenna is quite well designed. The center section of the boom is a healthy 1.5 inches in diameter. The remainder of the boom is tapered but still very strong. The rigid boom support braces should prevent wind vibrations, and can be placed either above or below the main boom — a big advantage where stacking frames are used and you want to keep all vertical mast lengths to a minimum.

The trigon assembly has been completely redesigned since the earlier Boomers to considerably decrease wind loading. In fact, this antenna has a wind load that's only slightly higher than the original 2-meter 32-19 Boomer, which has over a 6-foot shorter boomlength. I'm sure the Boomer XL will withstand our New England winters.

assembly

It took about 2-1/2 hours to assemble the 4218 XL. The directions, while brief, were adequate. All directors taper downward in length as clearly shown on the assembly instructions so element lengths can be easily verified. However, the rear boom section wasn't labeled, and, naturally, I assembled it backwards! However, when I tried to attach the trigon reflector, I noticed my error and quickly reassembled this boom section.

As with other Cushcraft products, all holes were precisely drilled and all the pieces fit together very nicely. All the hardware — even the "U" bolts — is stainless steel, a real plus. (There wasn't a spare piece of hardware, however, so *don't lose anything during assembly!*) Notice also that there are spare holes in the brace supports and trigon assembly that don't require hardware.

Before you assemble the balun, I'd recommend that you first check the connectors to see if they're tightened into the connector bracket. All that's needed is to grasp the connectors carefully on the back side of the plate with gas pipe pliers and turn them clockwise. Also solder the tips of the crimp type connectors used on the coax balun. Don't forget to apply the silicon grease provided, but only to the connector threads.

After final assembly, check all dimensions carefully, especially the boom sections and element lengths as shown on the diagrams provided. Next, mount the antenna on a 7- to 10-foot high mast or tower and test the VSWR using a 5- to 10-foot transmission line between the antenna and the VSWR meter. This test is highly recommended because it will often catch any assembly problems before the antenna is mounted in a hard-to-reach spot on the top of a tower. If desired, you can also take a few minutes to adjust the T-match strap position to minimize the VSWR at your favorite operating frequency.

test results

The 2-meter Boomer 4218 XL has a clean radiation pattern with high gain per unit boomlength.[2] From on-the-air tests I made, supplemented with computer analysis, a gain of 14.3 dBd was measured. This is as high or higher than any of the competition's antennas. VSWR measured at 144.2 MHz was less than 1.2:1 as specified, so I didn't even have to adjust the T-match! The measured VSWR was less than 1.5:1 from 144 through 144.8 MHz.

One final recommendation: during the manufacture of these antennas, an oily film apparently develops on the elements. This normally isn't a problem, but before it wears off, rain droplets may cling to the ends of the elements, thereby degrading the radiation pattern. So I'd recommend cleaning the ends of the elements with acetone or an equivalent solvent before assembly.

If you use a single 2-meter Boomer 4218 XL Yagi, it will probably work best mounted clear of other antennas. If this isn't possible, try to mount it at least one-half wavelength or at least 40 inches away from any other antennas on the same mast.

These antennas will stack very well; four should make a great 2-meter EME array. Cushcraft recommends 13 1/2 feet in the E (horizontal) plane and 12 1/2 feet in the H (vertical) plane. From my stacking experience, I think that these are very close to optimum.[3] If you do stack these Yagis, make sure not to flip them over or invert the feedlines.

Priced at about $150.00, this antenna is definitely recommended for the serious 2-meter operator. The boom is very long — almost 29 feet, which is quite large by VHF standards, so it isn't recommended for the fainthearted. However, this is a necessary evil if high gain on a single boom is desired. The beamwidth of a single 4218 XL is about 26 degrees, with the first side lobe down at least 16 dB. I'd strongly endorse this antenna for 2-meter tropo and EME operation.

For information, contact Cushcraft Corporation, 48 Perimeter Road, Manchester, New Hampshire 03108.

— **W1JR**

references

1. Stanley Jaffin, WB3BGU, "Applied Yagi Antenna Design Part 6," *ham radio*, October, 1984, page 89.
2. Joe Reisert, W1JR, "VHF/UHF World: Stacking Antennas — Part 1," *ham radio*, April, 1985, page 129.
3. Joe Reisert, W1JR, "VHF/UHF World: Yagi Facts and Fallacies," *ham radio*, May, 1986, page 103.

220-MHz base station xcvr

ICOM has introduced the first 220-MHz base station transceiver, the IC-375A, a deluxe all-mode radio that covers 216-230 MHz and has 99 tunable full-function memories, passband tuning, a notch filter, a noise blanker, a built-in SWR bridge, semi- or full CW break-in, a multi-function meter, "velvet touch" tuning, and an easy-to-read amber LCD readout with variable backlight. Four scanning systems are available: band, programmable, plus mode and memory scan with selectable lock-out that scans 99 memories in 5 seconds. All subaudible tones are built-in; the actual subaudible frequency is displayed. Standard repeater splits are built-in and odd splits are programmable.

For details, contact ICOM America, Inc., 2380 116 Avenue N.E., P.O. Box C-90029, Bellevue, Washington 98009-9029.

Circle #301 on Reader Service Card.

new high-powered VHF amplifiers

The new HL-250V25 high-power VHF amplifier for 2 meters from Tokyo HY-Power Labs, Inc., features a special combination of two separate modules, each capable of delivering over 125 Watts. It also provides an internal GaAs-FET preamplifier for pulling in weak signals.

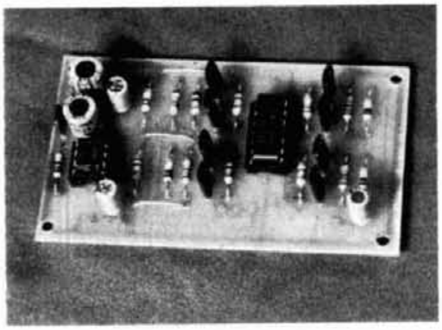
Priced at $459.95, the HL-250V25 requires 13.6 Vdc at 38 Amps maximum for power output of 250 Watts. For information, contact Encomm, Inc., 1506 Capital, Plano, Texas 75074.

Circle #303 on Reader Service Card.

active audio CW filter

The CW-1 Active Audio CW Filter is BEL-TEK's latest addition to its line of kits. The CW-1 eliminates QRM for easier copying and easily connects between your transceiver and speaker. The CW-1 has three selectable bandwidths (90, 130, and 200 Hz), with a center frequency of 800 Hz.

Priced at $19.95, the CW-1 measures 2 × 3.4 inches and can be powered by a 9-volt battery.



For more information, contact BEL-TEK, P.O. Box 125, Beloit, Wisconsin 53511.

Circle #304 on Reader Service Card.

repeater control board

The latest additions to the Creative Control Products line are the SRC-10 smart repeater control board and the PI-10/S link synthesizer board. The SRC-10 is a low-cost, low-power, self-contained microprocessor-based repeater controller. All repeater functions have been incorporated onto a 4 × 6-inch G-10 glass epoxy printed circuit board with one interfacing connector for ease of installation and reliability.

Priced at $149, the SRC-10 controller provides up to seven buffered auxiliary function control outputs selected remotely via a three-digit DTMF command. The SRC-10 controller responds with a Function Complete tone after each valid DTMF command. In addition to the Function Complete Tones are Auxiliary Function Tone Responses to indicate an ON or OFF condition. Courtesy Tone Responses are also available to indicate

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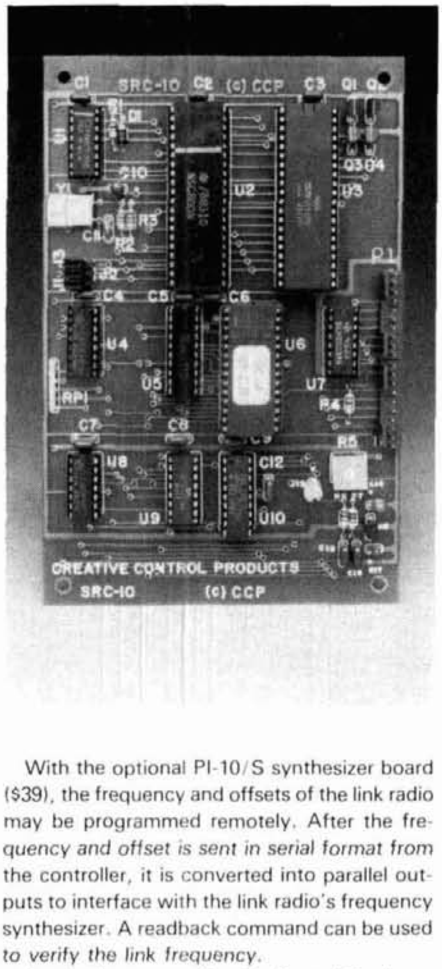
NEW products

repeater or link COS activity. There's also a lock command that's especially useful for dealing with jammers or hackers; when selected, the controller ignores all DTMF commands until the unlock command is received.



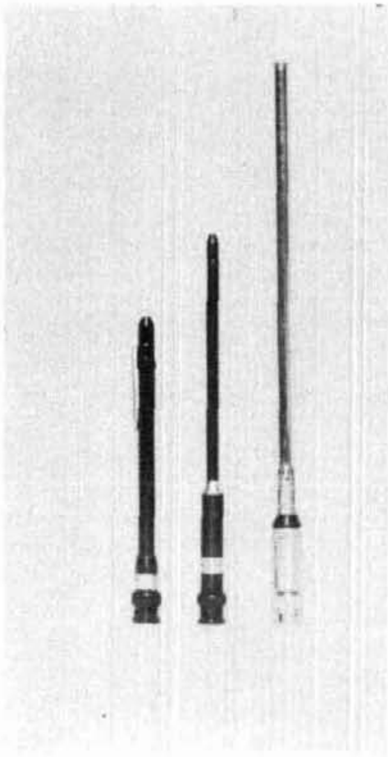
With the optional PI-10/S synthesizer board ($39), the frequency and offsets of the link radio may be programmed remotely. After the frequency and offset is sent in serial format from the controller, it is converted into parallel outputs to interface with the link radio's frequency synthesizer. A readback command can be used to verify the link frequency.

For details, contact Creative Control Products, 3185 Bunting Avenue, Grand Junction, Colorado 81504.

Circle #302 on Reader Service Card.

three new antennas

MFJ Enterprises, Inc. has announced the release of several new antennas. The MFJ-1710 ($9.95) is a 3/8-wave, 2-meter telescoping antenna with BNC. It comes with a convenient pocket clip and measures 5-3/4 inches collapsed and 24-1/2 inches fully extended.



The MFJ-1712 ($14.95) is a 1/4-wave 20-meter and 5/8-wave 440-MHz telescoping antenna with BNC. It measures 7-1/4 inches collapsed and 19 inches fully extended.

MFJ-1714 ($16.95) is a 1/2-wave 20-meter telescoping antenna with BNC. This unit is an end-fed, 1/2-wave dipole, which is shorter, lighter, has more gain and places less stress on the connector than a 5/8-wave mounted on a handheld. When collapsed, it performs like a rubber duck.

These MFJ products come with a double guarantee: order any product from MFJ. Try it. If you're not satisfied — for any reason — return it within 30 days for a complete refund (less shipping). MFJ products are also covered by a one-year unconditional warranty, so customers are assured of continued service.

For more information, contact MFJ Enterprises, Inc., P.O. Box 494, Mississippi State, Mississippi 39762.

Circle #305 on Reader Service Card.

hardware and software for Yaesu transceivers

The HF-Link line of hardware and software products provides a unique approach to controlling the Yaesu FT-980 and FT-757GX hf transceivers. Designed to interface with the Atari 8-bit family of microcomputers, the new products allow control of these transceivers with a standard joystick and eliminate the need for typing operating commands. They provide an accurate, on-screen graphic depiction of the transceiver's operational status; memory channel scanning at rates determined by the user; rapid updating of station logs; unlimited disk storage of log and memory channel data files; and performance of other functions even when the operator is absent.

For details, contact Wald-Easterday Associates, Inc., P.O. Box 16165, Columbus, Ohio 43216.

Circle #306 on Reader Service Card.

new antenna catalog

A new full-color, 12-page brochure shows Centurion International's complete line of antennas for portable radios, pagers, and cordless telephones, as well as accessory adaptors and cable assemblies. Included is a connector identification chart and list of radio models on which each style is used, making it easy to order the correct antenna.

For a free copy, contact Centurion International, Inc., P.O. Box 82848, Lincoln, Nebraska 68501.

Circle #307 on Reader Service Card.

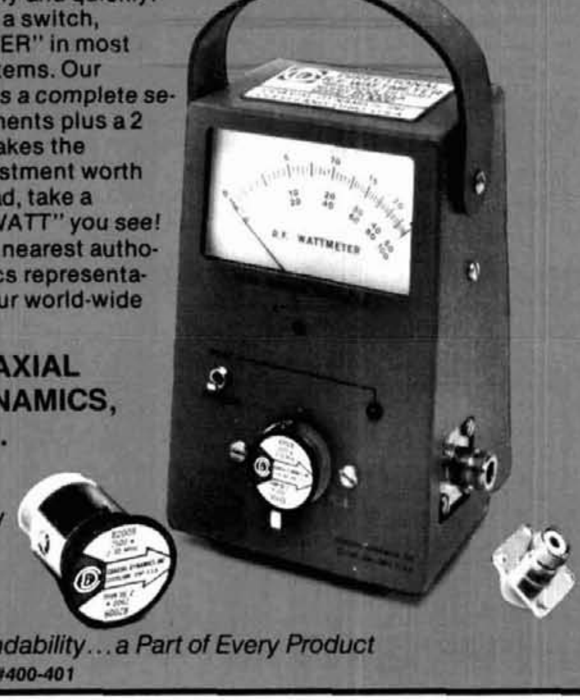
satellite receiver/ descramblers

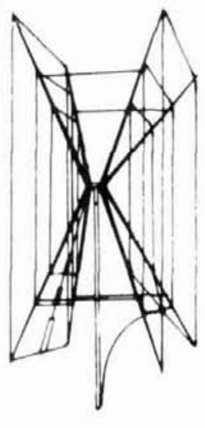
The new 2500R integrated satellite TV receiver and descrambler from General Instrument's VideoCipher Division combines the features and benefits of a receiver and a descrambler in a single unit. With the 2500R, consumers can purchase authorization to receive the descrambled signals of nine premium television programmers currently scrambling their satellite broadcasts (another 20 programmers intend to scramble their signals by the end of 1987).

Priced at approximately $1250, the VideoCipher 2500R, with wireless remote control, uses advanced circuitry that provides a threshold improvement of up-to 2 dB over other receivers, reduces "sparklies," and provides crisper images.

Other key features include two methods of parental supervision for controlling access to specific programming, a built-in terrestrial interference filter optimized for use with the VideoCipher II descrambler, programming for 24 C-band and 32 Ku-band channels, and digital stereo audio. An optional antenna positioner power supply allows users to program up to 21 satellites in memory and to program 10 channels on any satellite fo. instant recall by remote control.

The VideoCipher® II 2400R, a new lower-priced ($1050) integrated unit comes standard with wireless remote control, two methods of parental program supervision for controlling access to selected programming, fully programmable antenna positioner, programming for 24 C-band and 32 Ku-band channels, and digital stereo audio.





NEW products

For further information, contact General Instrument, Videocipher Division, 6262 Rusk Road, San Diego, California 92121.

Circle #309 on Reader Service Card.

circuit analysis program for the C-64

The new ALADYN-64 interactive circuit analysis program from Interceptor Electronics allows users to design linear ladder networks, commonly found in rf amplifiers and filters, on the Commodore 64 computer.

Formatted to simulate a vector network analyzer, the program permits the designer to select the frequency range over which the circuit will be tested. Output is in the form of S parameters on either a rectangular grid or Smith chart.

A disk drive is required; a printer is optional. The program, priced at $59.95 (postpaid) is written in BASIC and compiled for increased speed of operation.

For further information, contact Interceptor Electronics, Route 1, Box 439, Round Hill, Virginia 22141.

Circle #308 on Reader Service Card.

communications software packages

Kalt & Associates offers packet radio and multi-mode traffic handlers and other users several software packages for IBM and IBM-compatible PCs. Their Digipac II, for example, includes such exclusive features as full-screen editing (split-screen mode), full NTS traffic macro system, an alert alarm system with visual/audible/printer and disk control modes, "make-your-own" pop-up help screens, multi-sound alarms, "format-your-own" time/date/operator stamp, and user-defined function keys. Also available are full message forms, a pop-up help system, split screen, ASCII/binary file transfers, macro keys, macro files, DOS shell, character and line buffer mode, auto line-feed, disk logging, and other features. Scrolling function keys eliminate all the confusing ALT/commands common to other programs. Digipac II is priced at $49.95 plus $3.00 postage ($8.00 foreign).

The Message Form system is available independently for users who already have other communications software; it's priced at $29.95, with the same shipping rates.

For information, contact Kalt and Associates, 2440 E. Tudor Road, Suite 138, Anchorage, Alaska 99507.

Circle #311 on Reader Service Card.

ATV transmitter

The TX70-1 1-watt, 70-cm (420 to 450 MHz) ATV transmitter is a small (6 × 5.2 × 2.5-inch) unit designed to enable Technician or higher-class Amateurs to transmit live-action color or black and white composite video and audio from cameras, VCRs, or computers to other hams. The TX70-1 is a companion to the TVC-4G receiving downconverter.

The TX70-1 contains the improved KPA5-c transmitter board, which added a video monitor output of the actual modulated rf. Priced at $229 for single frequency, (a second crystal is available for $15), the unit has provisions for switching between two frequencies (the most popular frequencies are 426.25, 434.0 and 439.25). A switch is also provided to select video and audio input from either the 10-pin VHS-type home color cameras, or phono jacks for other cameras, VCRs, computers, or any composite video and line level audio source. A mic jack and "push-to-look" jack is available for low-impedance dynamic microphones and transmit/receive switching. The external power requirement is 12 to 14 Vdc at 500 mA plus whatever the connected 12-volt camera draws. The antenna connector is a type N, and a BNC outputs to the receiving downconverter from the built-in rf T/R relay.

The shielded cabinet of the TX70-1 is small enough to be carried in a knapsack for portable operation. Theoretical snow-free, line-of-sight DX using the 1-watt TX-70-1, TVC-4G downconverter and six-element KLM 440-6X beams is 5 miles. For greater DX with mobile or base applications, the output power and the sync stretcher in the video modulator of the TX70-1 matches the 50-watt Mirage D24N amplifiers' linear input vs. output range.

Licensed Amateurs can contact P.C. Electronics, 2522 Paxson Lane, Arcadia, California 91006, for more information and a complete catalog of this and other ATV products for the 70, 33, and 23 cm bands.

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R 7000
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Handheld for 2m/220/440
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TH 21BT/31BT/41BT
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COPY No special layout or arrangements available. Material should be typewritten or clearly printed (**not** all capitals) and must include full name and address. We reserve the right to reject unsuitable copy. **Ham Radio** cannot check each advertiser and thus cannot be held responsible for claims made. Liability for correctness of material limited to corrected ad in next available issue.

DEADLINE 15th of second preceding month.

SEND MATERIAL TO: Flea Market, Ham Radio, Greenville, N. H. 03048.

SMART BATTERY CHARGER for gell cells or lead acid batteries, by Warren Dion, W1BBH. See June '87 QST Magazine for circuit details. Complete kit, nothing else to buy, only $49.95 plus $3.50 s/h. Order #150-KIT. A & A ENGINEERING, 2521 W. LaPalma, Unit K, Anaheim, CA 92801. (714) 952-2114.

WANTED: WW2 Transceiver BC-654 (SCR 284) and PE-103 dynamotor. Also 1947/48 issues of Radio Craft and Radio & TV News magazines. E. Bircher, 108 Troy Drive, Slidell, LA 70461 (540) 649-7425.

FULL NTS TRAFFIC MESSAGE FORMS FOR PACKET OR RTTY on your IBM PC. MESSAGE-PAC works with any communications program to give you full Message Forms and formatted script/macro command files, ready to transmit. This is the one you've been waiting for. With user defined Pop-Up Help & Selection System that no one else offers. Can Pre-Load forms from disk. Only $29.95. DEMO DISK for $2.00. Write for information. Kalt and Associates, 2440 E. Tudor Rd, Suite 138, Anchorage, AK 99507. 907-248-0133. Charge Cards accepted.

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ANALOG AND RF CONSULTING for the San Francisco Bay area. James Long, Ph.D N6YB (408) 733-8329.

TEST EQUIPMENT WANTED. Don't wait – we'll pay cash for LATE MODEL HP, Tek, etc. Call Glenn, N7EPK, at Skagitronics Co. (800) 356-TRON.

"HAMLOG" COMPUTER PROGRAMS. 17 modules auto-logs, sorts 7-band WAS/DXCC. Full features. Apple $19.95, IBM or CP/M $24.95. KA1AWH, POB 2015, Peabody, MA 01960.

RV OPERATORS are invited to check in Sun 2 PMC, 14.240 ±5. Tues, Thurs 8 PMC 3.880 ±5. Good Sam RV Net. Info SASE KJ4RO.

CHASSIS, CABINET KITS. SASE. K3IWK, 5120 Harmony Grove Road, Dover, PA 17315.

TELEVISION SETS made before 1946, early TV parts, literature wanted for substantial cash. Especially interested in "mirror in the lid" and spinning disc tv's. Finder's fee paid for leads. Arnold Chase, 9 Rushleigh Road, West Hartford, Conn. 06117. (203) 521-5280.

ENGINEERS request free catalog of Electronics Software. Circuit analysis, filter design, graphics, etc. BV Engineering, 2200 Business Way, Suite 207, Riverside, CA 92501 (714) 781-0252.

REMEMBER TROLLEY CARS? *Trolley Treasures: The Wartime Years in New Jersey* (1939-1947), a 4-volume photodocumentary history, includes 1600 unpublished, original photographs plus extensive historical notes. Volume I, *The Compromise Roof Cars of Public Service Coordinated Transport*, ready now. SASE for details. To order, contact Trolley Themes, A.W. Mankoff, 2237-3 Woodside Lane, Sacramento, CA 95825. ($14.95 plus $1.50 S&H).

$$$$$SUPER SAVINGS on electronic parts, components, supplies and computer accessories. Free 40-page catalog for SASE. Get on our mailing list. BCD ELECTRO, PO Box 830119, Richardson, TX 75083 or call (214) 690-1102.

RTTY JOURNAL—Now in our 35th year. Join the circle of RTTY friends from all over the world. Year's subscription to RTTY JOURNAL, $10.00, foreign $15.00. Send to: RTTY JOURNAL, 9085 La Casita Ave., Fountain Valley, CA 92708.

IMRA International Mission Radio Association helps missionaries. Equipment loaned. Weekday net, 14.280 MHz, 1-3 PM Eastern. Nine hundred Amateurs in 40 countries. Rev. Thomas Sable, S.J., University of Scranton, Scranton, PA 18510.

DIGITAL AUTOMATIC DISPLAYS for FT-101's, TS-520's (DG-5 clone), Collins, Drake, Swan, Heath and all others. Six 1/2" digits. 5" wide by 1-1/4" high metal cabinet. Reads receive and transmit frequencies. Send $2.00 for information and receive a $30.00 discount. Includes accuracy comparison of the simple "BCD" readouts, found in new radios, against our "Calculating Frequency Counter" readouts. Please be specific. GRAND SYSTEMS, POB 2171, Blaine, Washington 98230.

WANTED-Manuals and Cables for type RBM-3 Rcvr, June 1942 and CCT-20086 power unit. D. Palmer, W6PHF, 638 Benvenue Avenue, Los Altos, CA 94022.

BACK ISSUES HR *Magazine from* Vol. 1 No. 1 thru 1986, except 2 issues. $150 for all postpaid. Also PopTronics, RE, 73 back to 1961. $15.00/full year. Write with your needs. Bill Fossman, 632 Wetmore, Everett, WA 98201.

COMMODORE REPAIR. We are the largest and oldest service center in the country. (eg. C64 repair-$39.95). 72 hour turnaround. Call toll Free 1-800-642-7634 (outside NY) 914-356-3131. Kasara Microsystems, Inc., 33 Murray Hill Drive, Spring Valley, NY 10977.

COMMODORE CUSTOM CHIPS for C64/128 Computer/Peripherals at low prices, 24 hour delivery: #6510-$9.55, #6526-$9.95, #6467-$14.75, #6581-$12.85, PLA-$10.95, 901 ROMS at $10.95 each, C128 ROMS-$39.95 (set of 3) and many others..."THE COMMODORE DIAGNOSTICIAN". A complete diagnostic reference chart for fixing Commodore computers, etc. An absolute must for those who want to fix their own computers and save money and down time. $6.95 plus postage...HD Power Supply for C64-$27.95...Send for complete chips/parts catalog. Kasara Microsystems, Inc., 33 Murray Hill Drive, Spring Valley, NY 10977. 800-248-2983 (outside NY) or 914-356-3131.

MARCO: Medical Amateur Radio Council, Ltd, operates daily and Sunday nets. Medically oriented Amateurs (physicians, dentists, veterinarians, nurses, physiotherapists, lab technicians, etc) invited to join. Presently over 550 members. For information write MARCO, Box 73's, Acme, PA 15610.

TUBES FOR SALE. New and used, old and current, 25 cents and up. Send list for quote. Ted Youngman, 2225 Vigo Street, Lake Satation, IN 46405.

HAM LICENSES SUPEREASY. Cut exam preps 50 percent. All classes. Free catalog. SASE. Bahr, 2459-H5 Temple, Palmbay, FL 32905.

XEROX 800 Electronic Typing System technical information or *schematics needed. TerryThompson, Box 935, Dania, FL* 33004-0935 (305) 920-1909.

HOMEBREW PROJECTS LISTS. SASE. WB2EUF, Box 708, East Hampton, NY 11937.

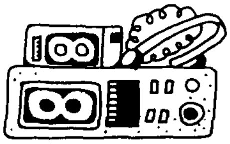
RUBBER STAMPS: 3 lines $4.50 PPD. Send check or MO to G.L. Pierce, 5521 Birkdale Way, San Diego, CA 92117. SASE brings information.

ELECTRON TUBES: Receiving, transmitting, microwave... all types available. Large stock. Next day delivery, most cases. DAILY ELECTRONICS, PO Box 5029, Compton, CA 90224. (213) 774-1255.

CUSTOM MADE EMBROIDERED PATCHES. Any size, shape, colors. Five patch minimum. Free sample, prices and ordering information. HEIN SPECIALTIES, Inc., Dept 301, 4202 N. Drake, Chicago, IL 60618.

RECONDITIONED TEST EQUIPMENT $1.25 for catalog. Walter, 2697 Nickel, San Pablo, CA 94806.

SATELLITE DISTRIBUTOR offers lowest prices on Winegard 10 ft. UPS shippable antennas, KU-LNB's 70 MHz Down Converters, and new IQ-160 boards. Best deals on MSE LNA's and LNB's, Starcast receivers, and actuators for Arunta and IQ-160. Master Card & Visa accepted. E.S.M., Inc., 1-800-457-0060 or 314-343-7745.



COMING EVENTS

Activities — "Places to go . . ."

SPECIAL REQUEST TO ALL AMATEUR RADIO PUBLICITY COORDINATORS: PLEASE INDICATE IN YOUR ANNOUNCEMENTS WHETHER OR NOT YOUR HAMFEST LOCATION, CLASSES, EXAMS, MEETINGS, FLEA MARKETS, ETC, ARE WHEELCHAIR ACCESSIBLE. THIS INFORMATION WOULD BE GREATLY APPRECIATED BY OUR BROTHER/SISTER HAMS WITH LIMITED PHYSICAL ABILITY.

CONNECTICUT: November 15. SCARA Indoor Ham Radio and Computer Flea Market, N. Haven Park and Recreation Center, 7 Linsley St, N. Haven. Sellers admitted at 7 AM; buyers from 9 AM to 3 PM. Tables are $10 in advance, $15 at the door. General admission $2 per person. Talkin on 146.61 MHz. Reservations for tables must be prepaid by November 4, 1987 and no reservation by phone. For information or reservations SASE to: SCARA, POB 81, N. Haven, CT 06473 or call Brad at (203) 265-6478 between 7 PM and 10 PM.

1987 "BLOSSOMLAND BLAST" Sunday, September 20, 1987. Write "BLAST" PO Box 175, St. Joseph, MI 49085.

OHIO: September 27. The Cleveland Hamfest Association's annual Hamfest and Computer Show, Cuyahoga County Fairgrounds, Berea. Doors open 8 AM to 4 PM. Early setup 6 AM. VE exams 9 AM. Tech forums and non-ham activities all day. Talk in on 146.52. Admission $3.50 advance; $4.00 at the gate. Inside tables $10. Outside flea market $4.00. Saturday night banquet. For more information write C.H.A., POB 81252, Cleveland, OH 44181-0252.

ILLINOIS: September 12. The Northern Illinois DX Association invites all Amateurs to attend the 35th annual W9DXCC DX Convention, Holiday Inn, 1250 Roosevelt Road, Glen Ellyn. For information and registration: Howie Huntington, K9KM, 65 South Burr Oak Drive, Lake Zurich, IL 60047.

NEW JERSEY: September 20. The South Jersey Radio Association, the oldest continuously operating radio club in the US, will hold its 39th annual Hamfest, Pennsauken Senior High School, Rt 73 and Remmington Ave, Pennsauken. 8 AM to 2 PM. Tickets $3/gate; $2.50/advance. Sellers $5 per space plus admission. VE testing all classes. Registration 9:30 AM. Refreshments available. Talk in on 145.290. For more info or tickets contact Fred Holler, W2EKB, 348 Bortons Mill Rd, Cherry Hill, NJ 08034 (609) 795-0577.

NEW JERSEY: September 13. The DeVry Tech ARC will have a Ham Radio/Computer flea market, school parking lot, 479 Green Street, Woodbridge. 9 AM to 5 PM. Vendors setup 7 AM. Sellers $3/per car space. 2 free spaces for non-profit organizations. Buyers admitted free. For information call Linda (201) 634-3460 days and Frank, WB2JKU (201) 787 0818 evenings.

OREGON: September 26-27. The Walla Walla Valley ARC will hold its annual Hamfest, Oregon Community Building in Milton-Freewater. 8 AM to 5 PM. Tables and admission FREE. Exams both days. Walk-ins accepted. For more information contact Bernie Frazier, WA7CBX, 610 S. First Avenue, Walla Walla, WA 99362 or phone (509) 529-9879.

MINNESOTA: September 26. The Viking ARS will host its 17th annual Swapfest, Waseca High School, Waseca. Doors open 8 AM. Talk in on 34/94. Formore information contact VARS, POB 3, Waseca, MN 56093.

CONNECTICUT: September 13. The Candlewood ARA's annual Flea Market, Danbury Elks Club, 346 Main Street, Danbury. 9 AM to 3 PM. Dealers 8 AM. Admission $3. Tables $8. Tailgating $5. Talk in on 147.72/12. For table reservations send check or MO to CARA c/o Gene Marino, 31 Valley View Rd, Newtown, CT 06470 or call Gene at (203) 426-8852.

GEORGIA: September 27. The Lanierland ARC will hold its 14th annual Hamfest. New Location- Georgia Mountain Center near Holiday Inn, Gainesville. 8:30 AM to 3 PM. VE exams 9 AM. Free admission. Free tables for dealers registering early. Talk in on 146.07/.67. Contact Phil Loveless, KC4UC, 4949 Red Oak Drive, Gainesville, GA 30506 (404) 532-9160.

ALABAMA: September 12 and 13. The Mobile ARC sponsored Hamfest, Texas Street Recreation Center, Mobile. Doors open 9 AM. Admission $2.00 for both days. Dealers, swap tables, non-ham activities, free parking. Also free overnight parking for SCRV's. Hospitality room Saturday night. Talk in on 146.22/82. For table reservations write MARC, POB 7232, Mobile, AL 36607. Phone N4MFQ (205) 471-4717 or KB4JET (205) 865-4404.

CONNECTICUT: September 27. The 5th annual Natchaug ARA giant flea market, Elks Home, 198 Pleasant Street, Willimantic. Starts 9 AM. Dealers 8 AM. Admissin $2. Under 16 free. Advance inside tables $5.00. At the door $7.00. Outside tailgating $5.00/up. ARRL/VEC exams for all classes. Talk in on 90/30 and 52. For information Ed Sadeski, KA1HR, 49 Circle Drive, Mansfield Ctr (203) 456-7029 after 4 PM.

IOWA: October 4. Southeast Iowa Hamfest, sponsored by the Muscatine and Iowa City Radio Clubs, West Liberty, Iowa Fairgrounds. Gates open 7 AM. Tickets $3/advance and $4/gate. Saturday night all-you-can-eat weiner roast, hay rides, flea market and fox hunt. Talk in on 146.31/.91, 146.25/.85 and 146.52. For information KA0Y, Ken, (319) 648-5037 or KE0Y, Tom, (319) 264-3259.

MISSOURI: September 27. The St. Peters ARC will hold its third annual Swapfest, Golden Triangel Park in St. Peters. 6 AM to 2 PM. Admission $1.00 to buy or sell. Expanded flea market and parking areas. Food and beverages available. For more information contact Jason Zwyers, KA0INR, 1084 Crestwood Lane, O'Fallon, MO 63366.

NEW YORK: September 20. LIMARC ARRL Long Island Hamfair, New York Institute of technology, Rt 25A, Northern Blvd, Old Westbury, NY. General admission $3.00. Sellers 7:30 AM. Buyers 9 AM. Outdoor tailgating, no reservations. Sellers car space $5. For more information Hank Wener, WB2ALW (516) 484-4322 evenings.

GEORGIA: September 20. Augusta Amateur Radio Club will hold its annual Hamfest, Julian Smith Casino, Lake Olmstead Park, Augusta. 9 Am to 3:30 PM. Tickets $2.00 at Hamfest. Talk inon 146.34/94. For more information N4JA (404) 790-7802.

MICHIGAN: October 25. The Southwest Michigan AR Team and the Kalamazoo ARC are sponsoring the 5th annual Kalamazoo Hamfest. New larger location – Kalamazoo Central High School, 2432 N. Drake Road. 8 AM to 4 PM. Walk in VE testing. Admission $2/advance, $3/door. Tables $6. Send requests and check with SASE by September 28 to Jim Hastings, Kalamazoo Hamfest, 1813 Greenbriar Drive, Kalamazoo, MI 49008.

PENNSYLVANIA: October 10-11. The Pack Rats (Mt. Airy VHF ARC) invites all Amateurs and friends to the 11th annual Mid-Atlantic VHF Conference, Warrington Motor Lodge, Rt 611, Warrington, PA and our16th annual Hamarama October 11 at the Bucks County Drive-In Theater, Rt 611, Warrington, PA. Advance conference registration $5; $6 at the door (includes admission to the flea market). Send to Hamarama '87, POB 311, Southampton, PA 18966. Admission to the Flea Market $4. per person; $7 per carload. Selling spaces $6/each. Bring tables. Gates open 6 AM rain or shine. For information Pat Cawthorne, WB3DNI (215) 672-5289.

NEW MEXICO: September 26-27. The Northern New Mexico ARC's 4th annual Hamfest, Camp Stoney, 8 miles east of Santa Fe. 8 AM to 3 PM. Forums, tailgate flea market, dealers and Sat. AM VEC exams. Also non-ham programs. For more information SASE to bob Norton, N5EPA, Rt. 3, Box 95-15, Santa Fe, NM 87505.

NEW YORK: September 12. Saratoga County R.A.C.E.S. Association's 2nd annual Hamfest, Saratoga County Fairgrounds, Ballston Spa. 9 AM to 5 PM. Forums, packet demos, 2m fox-hunt, contests and more. Admission $3 includes outside selling space. Inside space $3/8 table. Talk in on 147.00 or 147.24. For more information N2FEP, Dave Atwell, Box D15, RD 5, Ballston Spa, NY 12020.

PENNSYLVANIA: September 12. The W3PIE Uniontown ARC will hold its 38th annual GABFEST, old Pittsburgh Rad, Uniontown. Pre-registration $3 each or 2/$5. Free parking, free swap and shop setup with registration. Talk in on 147.045/645 and 144.57/145.17. For more info John T. Cermak, WB3DOD, POB 433, Republic, PA 15475 (412) 246-2870 or 246-9383.

WASHINGTON, DC. September 27-29. The annual convention of the Microwave Communications Association, Ramada Renaissance Hotel. For information: Elena Selin, 2000 L Street NW, Suite 200, Washington, DC 20036. (301) 464-8408.

COLORADO: September 27. TheBoulder ARC will sponsor its annual BARCFEST Swap Meet, National Guard Armory, 4750 North Broadway, Boulder. 8 AM to 3 PM. $3. donation. Tables $3. VE tests start 9:30 AM. Food and refreshments available. For VE test info only Barbara McClune, N0BWS, 5338 Spotted Horse Trail, Boulder, CO 80301 (303) 530-1872. For BARCFEST info Dale Scott, KA0QPV, 304 E. Cleveland St, Lafayette, CO 80026. (303) 665-2364.

NEW HAMPSHIRE: October 10. The Hosstraders will hold their Fall Tailgate Swapfest, Deerfield Fairgrounds. Admission $2 per person. Sellers included. Wheelchair accessible. Friday night camping at nominal fee (after 4 PM only). Profits benefit Shriners' Hospitals. Our May 1987 donation was over $8,000! For map or info SASE to Norm Blake, WA1IVB, RFD Box 57, West Baldwin, ME 04091.

NEW YORK: September 26. Orange County ARC's 2nd annual Hamfest and Computer Fair, John S. Burke Catholic High School, Fletcher Street, Goshen. Donation $2. Indoor tables $5 each admits one. Outdoor spaces $3 each, admits one. Talk in on 146.76 repeater. For information and reservations: Barbara Christopher, N2AWI, Box 447, RD 2, Wallkill, NY 12589.

NEW YORK: September 26. The Elmira ARA will hold its 12th annual International Hamfest, Chemung County Fairgrounds. 6 AM to 5 PM. Outdoor flea market, indoor dealer displays, breakfast and lunch served on the premises. Tickets available at the gate or from Steve Zolkosky, 118 East 8th Street, Elmira Heights, NY 14903.

NEW YORK: September 12. Ham-O-Rama 87, the Niagara Frontier International Hamfest and Computer Show sponsored by the 5 Amateur Radio clubs on the Niagara Frontier. Niagara Falls Convention Center just north of Buffalo. Tickets $3.50 before August 21; $5.00 at the gate. Children under 12 admitted free. New equipment, video displays, non-technical programs, flea market. Parking facilities for the handicapped. Many nearby attractions. For information contact Bernie Norman, POB 352, Cheektowaga, NY. (716) 877-3780.

ILLINOIS: September 20. "OPEN HOUSE- World of Amateur Radio" will be conducted by the Chicago ARC, North Park Village, 5801 N. Pulaski, Chicago. 11 AM to 5 PM. For information call 545-3622. Novice class license seminar starts September 28 at 7:30 PM for 10 weeks.

TEXAS: September 19-20. The annual WARS Hamfest, Wichita Falls Activity Center, 10th and Indiana Streets. 8 AM to 4 PM Saturday and 8 AM to 2 PM Sunday. Commercial displays, computer goodies, homebrew contest, large inside flea market. Advance registration $6 by September 16. At the door $7. Swap tables $5 each. VE exams 1 PM Saturday. Walkins accepted. Talk in on 74/14, 34/94, 449.30/4.30. Mail prregistration and table request with check to WARS Hamfest, POB 4363, Wichita Falls, TX 76308.

NEW YORK: October 4. The Yonkers Amateur Radio Club's Electronics Fair and Giant Flea Market, Yonkers Municipal Parking Garage, Nepperhan Avenue and New Main Street, Yonkers. 9 AM to 4 PM. Giant Auction 2 PM. Live demos all day. Free coffee all day. Admission $3. Children under 12 free. Sellers $7 per parking space, admits one, bring own tables. For further information call (914) 969-1053.

MASSACHUSETTS: October 10. The annual meeting and banquet of the New England DXCC Association will be held at the Masonic Lodge in historic Concord. Meeting 2 PM. Banquet 6:30 PM. The group is celebrating its 35th anniversary and will have a special program featuring recent DX-Peditions by some members to the Ivory Coast and senegal.

MASSACHUSETTS: MIT Tailgate electronics, computer and Amateur Radio Flea Market, Albany and Main Sts, Cambridge. 9 AM to 4 PM. Admission $1.50. Free off-street parking for 500 buyers. Sellers $5 per space includes 1 admission. Setup 7 AM. Call (617) 253-3776. Mail advance reservations by September 10 to MITUHFRA c/o 4 Madison Street, Belmont, MA 02178. Talk in on 146.52 and 449.2/44.2 pl 2A W1XM/R.

MICHIGAN: September 19. Grand Rapids Amateur Radio Association will host its annual Swap & Shop, NEW LOCATION - West Cathkolic High school, 1801Bristol NW, Grand Rapids. Doors open 8AM. Tickets $3. Tables $4 each. No trunk sales this year. Talk in on 86/26 and 224.64. For table reservations or information call Don Hazelswart, KA8BCI (616) 363-0649 or write POB 1248, Grand Rapids, MI 49501.

WISCONSIN: September 20. The Tri-county ARC, W9MQB, will hold its "Fall-Fest", Blackhawk Technical Institute, Hwys 51, between Beloit and Janesville. 7 AM to 3 PM. $2.00 per person. Bring your own tables for flea market. Talk in on 145.45 and 146.52. For more information: Carl Searing III, KW9W, 249 N. Tratt Street, Whitewater, WI 53190.

CALIFORNIA: September 19. The Sonoma County Radio Amateurs will hold their fifth annual Ham Radio Flea Market, Sebastopol Community Center, 390 Morris Street, Sebastopol. 8 AM to 2 PM. Free admission and parking. Tables $7/door; $5/advance. Vendor setup 7 AM. VEC exams, radio clinic, exhibits, refreshments, auction. Talk in on 146.13/73. For tickets and information write SCRA, Box 116, Santa Rosa, CA 95402.

OPERATING EVENTS

"Things to do . . ."

September 11. The Quinnipiac Council - B.S.A. will operate W1GB during the first annual Trader-O-Ree at Camp Sequassen, Winsted, CT. For special QSL, send QSL and SASE to KA1EAJ, Skip Paquette, 121 West Dayton Hill, Wallingford, CT 06492.

September 18-20: The Wright-Patterson AFB MARS, AGA1WP and the Dayton Amateur Radio Association, W3BI will go on the air to commemorate the celebration of the Air Force's 40th anniversary. For further information write Paula DiGennaro, KA8HQJ, 7136 Pineview Drive, Huber Heights, Ohio 45424.

September 19-20: The Wellesley Mass ARS will operate W1TKZ to celebrate the new Novice 10 meter privileges. 1300Z to 0100Z. All Amateurs are welcome especially Novices and Technicians. For a special QSL card send QSL and SASE to Wellesley ARS, 211 Washington St, Wellesley, MA 02181.

September 19: The South Canadian Amateur Radio Society will celebrate its decicentennial by operating special event station W5OU from 1400Z-2400Z. For certificate send QSL and 9x12 SASE with 39 cents postage to SCARS c/o KD5IT, 2735 Poplar Lane, Norman, OK 73072.

September 15-19. The Southern Counties ARA will operate K2BR during the Miss America Pageant, Atlantic City, New Jersey. QSL SASE via SCARA, Box 121, Linwood, NJ 08221.

September 27-28. 1987 Fall Classic and Homebrew Radio Exchange. 2000 UTC Sunday to 0400 UTC Monday. Our object is to restore, operate and enjoy older and/or homebrew equipment of any vintage. CW call "CQ CX"; phone "CQ Classic Exchange".

September 5-6. The Porter County ARC will operate N9RD from 1300Z to 2300Z from the Heston Steam Museum for the annual Steam Show. For further info contact Jurgen, N9RD or Tom, KB8AC, POB 1782, Valparaiseo, IN 46383.

September 26-27: The Council of Eastern Mass. Amateur Radio Clubs (CEMARC) will operate special event stations during the Amateur Radio exhibit at the Museum of Science in Boston, MA. Each station will use the call sign KA1SM.

HAM EXAMS: The MIT UFH Repeater Association and the MIT Radio Society offer monthly Ham Exams. All classes Novice to Extra. Wednesday September 23, 7 PM, MIT Room 1-150, 77 Mass Ave, Cambridge, MA. Reservations requested 2 days in advance. Contact Ron Hoffmann at (617) 646-1641. Exam fee $4.25. Bring a copy of your current license (if any), two forms of picture ID, and a completed form 610 available from the FCC in Quincy, MA (617) 770-4023.

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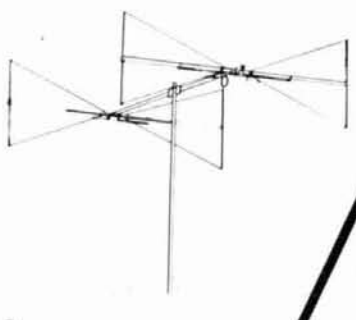

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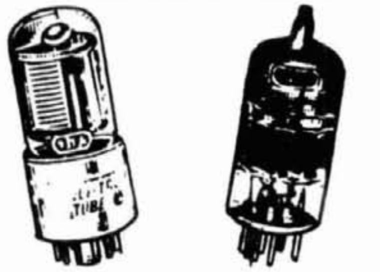

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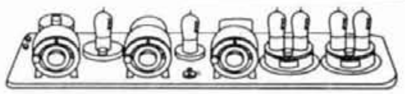

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ELMER'S NOTEBOOK

Tom McMullen, W1SL

an introduction to AMTOR

It's digital communications time again, after a brief detour into discussion of the 28- and 220-MHz bands.[1]

July's column covered the basics of RTTY and ASCII, two foundations for more advanced teleprinter communications techniques. This month we'll continue with a look at AMTOR, another aspect of modern digital communications.

In referring to teleprinters, by the way, I'm not limiting the discussion to mechanical devices that print on paper; the term can also apply to electronic systems that "print" their output on a cathode-ray-tube screen (CRT).

QRN here...

One of the problems that has plagued teleprinter communications from the beginning is noise. Oh, sure, noise bothers CW and voice operators too, but that computer most of us have between our ears has a marvelous ability to fill in missing portions of a word or phrase when a static crash or some other noise blots out the signal for a brief period of time. The machinery of teleprinting isn't so smart — it can't infer what was "probably" sent by examining the context of the message. In mechanical systems such as RTTY, a mangled or missing bit of data will result in either a wrong character or no character being printed. In electronic systems using computers or "dumb" terminals,* improper data can still print a wrong character, but if the noise mangled an instruction, the system is likely to "lock up." Often, the only recovery is to shut the equipment off and then turn it on again, which loses any data already received. (And you thought first-contact jitters were bad! Be thankful you're not a computer.)

As all good traffic handlers know, when the message must get through despite poor conditions, a solution to the noise problem is to repeat what's being sent. Accuracy is improved, but throughput (that's a buzzword referring to amount of information transferred per unit of time) is reduced. It's a tradeoff that's acceptable when accuracy is most important.

AMTOR to the rescue

AMTOR is a modern way of doing just that — repeating what is sent. The system was adapted from a commercial scheme devised to improve the reliability of communications with maritime units where garbled text could result in costly delays. The acronym AMTOR comes from AMateur Teleprinting Over Radio.

AMTOR comes in two flavors, Mode A and Mode B. In addition to repeating what's sent, both use a unique code characteristic to allow the receiving station to reject bad data. **Figure 1** shows the letter "Y" in both Baudot and AMTOR codes.

The AMTOR code was developed from the Baudot (or RTTY) code, and there's a direct correlation in most of the characters. The binary representation of "Y" in Baudot is 10101; you'll note that the center five bits of the AMTOR "Y" are also 10101.

Here's where AMTOR gets clever. There's always a ratio of four marks (ones) to three spaces (zeros). This is accomplished by adding ones or zeros to the original five-bit code. If the receiving station finds a character without that ratio, it rejects it as bad data.

In Mode A AMTOR, one station is called a "master," and the other a "slave." The master station is the station that initiates the contact. After contact is established, the master is known as the "information-sending station," or *ISS*. The slave becomes the "information-receiving station," or *IRS*. These roles can be reversed during the contact by either station sending the proper control code to the other. Mode B doesn't use the master/slave concept, but instead repeats the characters being sent in a pattern designed to minimize errors.

* A "dumb" terminal is one that can only receive, display, and transmit text; a "smart" terminal contains a microprocessor and circuitry that allows it to also perform complex computing and data-manipulating functions.

Note that packet radio, through computerized error-checking, offers the advantage of noise-free, error-free communication; we'll discuss packet radio in a future column.

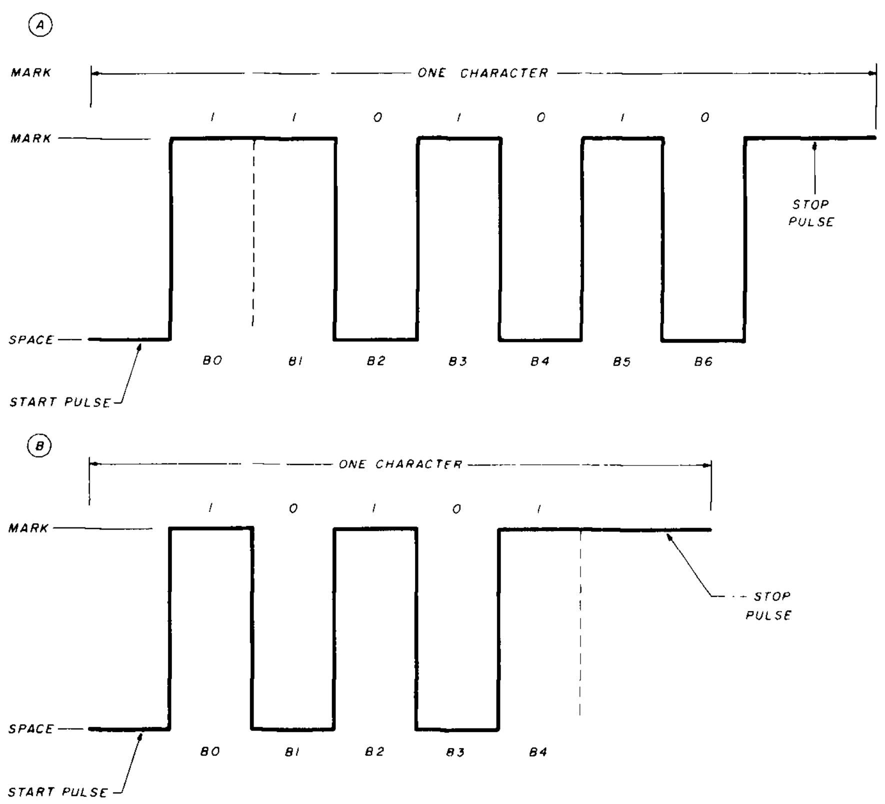

fig. 1. The letter "Y" in AMTOR code at (A), and in Baudot (RTTY) code at (B). The seven-bit AMTOR code was developed from the five-bit Baudot code by adding 1s and 0s to permit checking for accuracy of received bits. Compare these to the ASCII letter "Y" in my July column.

slaving away

In Mode A, the ISS transmits data in groups of three characters, then waits for an acknowledgment. The IRS receives the data and checks it for the constant 4:3 ratio; if the data is good, the receiving station sends an acknowledgment signal in the form of a special control code. The ISS then sends another group of three. If the IRS gets bad data or misses something, it sends a control character that asks for a repeat. Thus, the contact, or QSO, is a series of bursts of data going back and forth.

The transmission rate is usually 100 baud. The transmission of each character requires 70 milliseconds to send, for a group time of 210 msec. The master waits 240 msec for a reply before sending the next group (or repeating the group just sent). This on-and-off operation means that your transmitter will operate with slightly less than 50-percent duty cycle, and shouldn't overheat at reasonable power levels. It also means that your equipment should have fast "turn-around" times in switching from send to receive and back again.

AMTOR equipment has an adjustment to compensate for equipment switching time. If your equipment is too slow, your receiver won't be ready in time to hear the acknowledgment from the IRS; if it's too fast, you'll send the next group before the IRS is ready to copy it. Another type of delay can result from the propagation time between the ISS and the IRS: nearby contacts require less propagation time than those half a world away. AMTOR equipment can also be adjusted to tailor this time for optimum results. (Reliability has its price. There's no free lunch anywhere!)

Obviously, this system is slow. The extra bits, the processing time, and the time spent waiting for an acknowledgment all add up. Even though these times are each only a few milliseconds long, the total lengthens the time required to send information. At 100 baud, however, the speed of data transfer is still faster than most people can type, so the extra bits and wait times aren't too objectionable. A good circuit will transfer data at the rate of approximately 50 wpm. This speed will decrease as conditions get worse, slowing to about 10 wpm as the signal deteriorates, but the system will continue to try for correct copy (talk about dedicated operators!).

There's a catch, though: what if you don't want to use the one-on-one situation where one station is the master and the other is the slave? Perhaps you want to send a message to a network of stations or to one station with others to copy. The first station to acknowledge would be the IRS, and all others would be locked out. Then, too, there must be a mode that allows you to call CQ.

Here's where Mode B comes in. In this system, each character is repeated in a sequence that is calculated to get the information through most accurately. If you know the approximate length of the average noise burst (such as QRN from lightning), and you repeat the characters at intervals slightly longer than that noise-burst length, you have a pretty good chance of getting your message across. That's just what Mode B does.

For example, if I send "antenna here is 3-element beam," but noise wipes out some of it, you might receive "a—en-a h—e is—ele—nt bea-." Your between-the-ears computer can probably deduce what I meant. But if our QSO is being carried out on teleprinter devices, each machine will print what it receives; this can lead to some pretty garbled text because noise bursts can be interpreted as almost anything, even unprintable characters. (No, I'm not talking about a prudish machine that censors the text, but about those control characters that don't print a letter or number, but rather ring a bell, advance the paper, or shift to upper case, for example.)

Now suppose I repeat the message so you can fill in the missing pieces. On the first transmission you receive "a—en-a h—e is—ele—nt bea-." The second time, you receive "-nte-na -ere -s 3 —emen- —am." You can fill in the missing pieces and recover the whole message easily enough, but now the beauty of it all is that your receiving machinery can do the same, and a whole lot faster. Instead of repeating the whole sentence, suppose that I know that the average noise burst is likely to be approximately two to three characters long. If I repeat the text in groups of four, the chances of the message getting through are much greater, and the amount of time spent repeating is kept to a minimum. Again, transmission is at 100 baud, so each character takes 70 msec, for a total of 280 msec for the first transmission; repeat the first four characters, then send the next four and repeat them. The sending sequence for the message above might be:

Ante|ante|nna |nna |here|here| is | is |thre|thre|e el|e el|emen|emen|t bea|t be|am. |am. |

I've inserted the vertical bar (|) to mark off the groups of four characters; it isn't sent as part of the message. Note that spaces between words count as "characters" too; in AMTOR code, each space is indicated as 0011101 (bit 0 first).

In Mode B, the transmitter is on continuously, so it might overheat unless it's designed to handle continuous duty cycle. If this is the case, reduce the power level to something that the transmitter can handle. (Like AMTOR operation, RTTY also requires that most transmitters be operated at reduced power to prevent overheating. Check your equipment instruction manual for duty-cycle information.)

If all this seems complicated and confusing, don't worry — it probably is. The good news is that you don't have to think too much about it; today's equipment has a lot of "smarts" built in. All you need is a teleprinter, a terminal, or a personal computer; add an AMTOR encoder/decoder box, connect it to your transceiver, and watch the lights blink.

Well, maybe it's not quite that easy, but it's not too hard, either. You'll still have to learn how to tune in a station, and what the operating procedures are, but a little careful listening (make that "monitoring") will take care of the latter. For practice in tuning in a station (and learning what one sounds like) tune in W1AW, the Maxim Memorial Station at ARRL headquarters in Newington, Connecticut. The station transmits bulletins on AMTOR Mode B on 14,095 kHz at scheduled times. Novices: remember, you can receive (listen) in Mode B on hf bands other than 10 meters, but you can transmit (reply) in either mode *only between 28.1 and 28.3 MHz*.

Other "listening" spots are 14,075 and 3637.5 kHz. Many stations start there and then move a few kHz up or down to continue QSOs. If you hear a "chirp-chirp" type of operation, it's probably two stations using Mode A. If a signal sounds very much the same as a continuous RTTY signal, it could be either RTTY or Mode B. If you tune it in and the lights on your AMTOR box come on, you're doing something right. Try some schedules on 10 meters and have a ball.

There's more interest in AMTOR in Europe than in the United States, so here's a chance to grab some very interesting DX on a relatively new and fascinating mode of communication.

reference

1. Tom McMullen, W1SL, "Elmer's Notebook: An Introduction to Digital Communications," *ham radio*, July, 1987, page 92.

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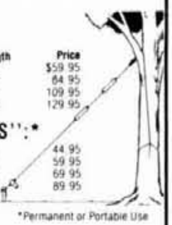

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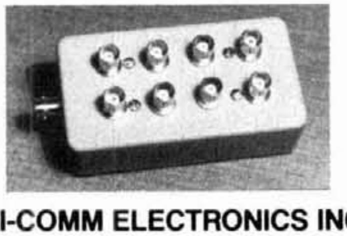

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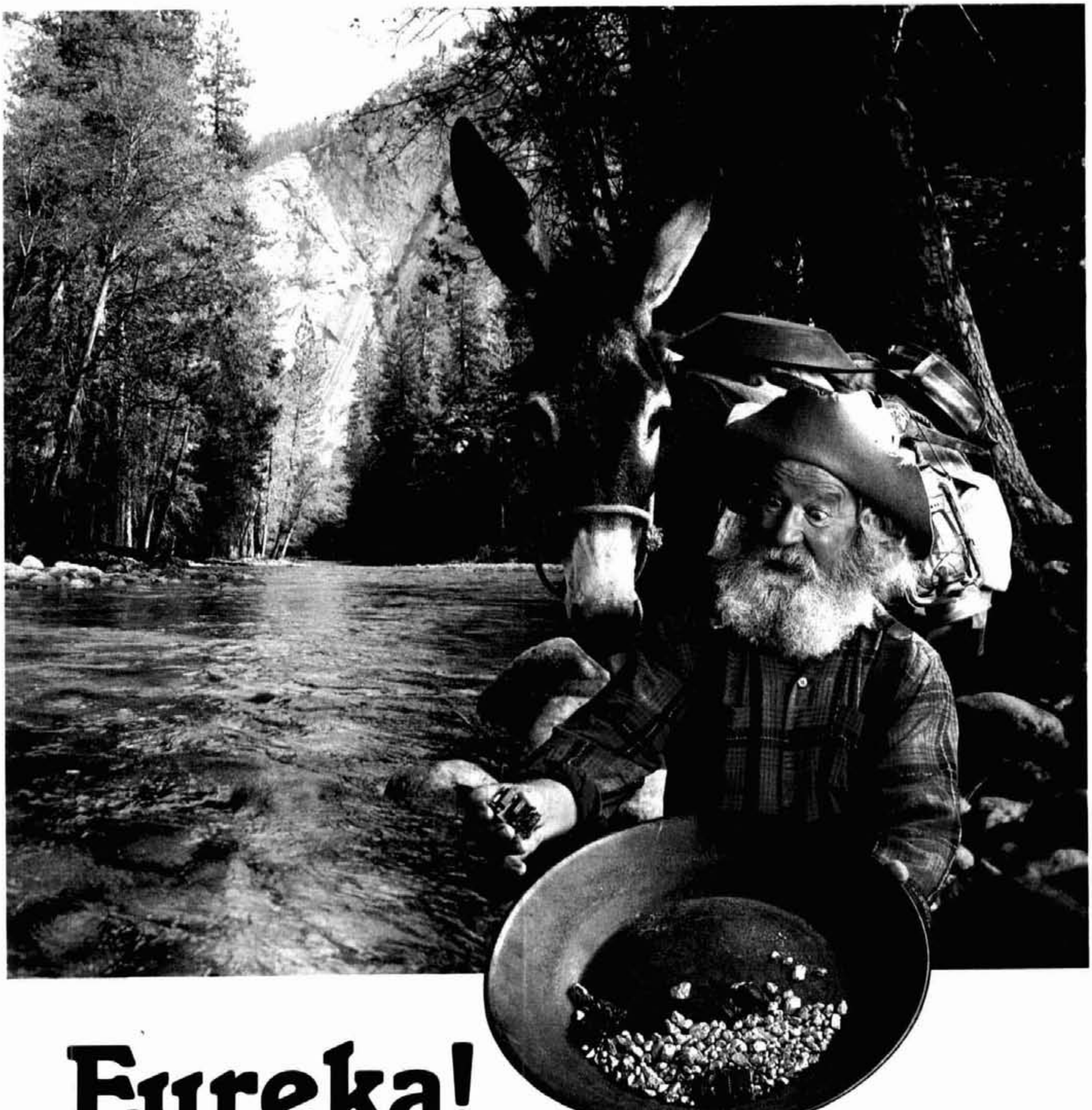

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The excellent sensitivity of the 1200H makes it ideal for use with the telescoping RF pick-up antenna; accurately and easily measure transmit frequencies from handheld, fixed, or mobile radios such as: Police, firefighters, Ham, taxi, car telephone, aircraft, marine, etc. May be used for counter surveillance, locating hidden "bug" transmitters. Use with grid dip oscillator when designing and tuning antennas. May be used with a probe for measuring clock frequencies in computers, various digital circuitry or oscillators. Can be built into transmitters, signal generators and other devices to accurately monitor frequency.

The size, price and performance of these new instruments make them indispensible for technicians, engineers, schools, Hams, CBers, electronic hobbyists, short wave listeners, law enforcement personnel and many others.

STOCK NO:

#1200HKC	Model 1200H in kit form, 1-1200 MHz counter complete including all parts, cabinet, Ni-Cad batteries, AC adapter-battery charger and instructions	**$ 99.95**
#1200HC	Model 1200H factory assembled 1-1200 MHz counter, tested and calibrated, complete including Ni-Cad batteries and AC adapter/battery charger	**$137.50**
#1300HC	Model 1300H factory assembled 1-1300 MHz counter, tested and calibrated, complete including Ni-Cad batteries and AC adapter/battery charger	**$150.00**

ACCESSORIES:

#TA-100S	Telescoping RF pick-up antenna with BNC connector	**$12.00**
#P-100	Probe, direct connection 50 ohm, BNC connector	**$18.00**
#CC-70	Carrying case, black vinyl with zipper opening. Will hold a counter and accessories	**$10.00**

1.3 GHZ

#1300H

✓ 169

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Of course, the FT-757GX/II offers the kinds of options you'd expect from Yaesu, too. Including standard and heavy-duty power supplies, automatic antenna tuner, and more.

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Prices and specifications subject to change without notice.

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220 MHz TM-321A Coming Soon!

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TM-221A/321A/421A

2 m and 70 cm FM compact mobile transceivers

The all-new TM-221A, TM-321A and TM-421A FM transceivers represent the "New Generation" in Amateur radio equipment. The superior Kenwood GaAs FET front end receiver; reliable and clean RF amplifier circuits, and new features all add up to an outstanding value for mobile FM stations! The optional RC-10 handset/control unit is an exciting new accessory that will increase your mobile operating enjoyment!

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- TM-321A covers 220-224.995 MHz. The TM-421A covers 438-449.995 MHz.
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- Microphone test function on low power.
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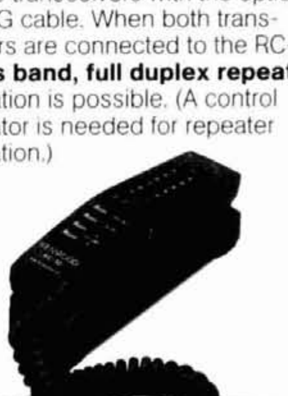
RC-10 Remote Controller

For TM-221A/321A/421A. Optional telephone-style handset remote controller RC-10 is specially designed for mobile convenience and safety. All front panel controls (except DC power and RF output selection) are controllable from the RC-10. One RC-10 can be attached to two transceivers with the optional PG-4G cable. When both transceivers are connected to the RC-10, **cross band, full duplex repeater** operation is possible. (A control operator is needed for repeater operation.)



Optional Accessories:

• **RC-10** Multi-function handset remote controller • **PG-4G** Extra control cable, allows TM-221A/TM-421A full duplex operation • **PS-50/PS-430** DC power supplies • **TSU-5** Programmable CTCSS decoder • **SW-100A** Compact SWR/power/volt meter (1.8-150 MHz) • **SW-100B** Compact SWR/power/volt meter (140-450 MHz) • **SW-200A** SWR/power meter (1.8-150 MHz) • **SW-200B** SWR/power meter (140-450 MHz) • **SWT-1** Compact 2 m antenna tuner (200 W PEP) • **SWT-2** Compact 70 cm antenna tuner (200 W PEP) • **SP-40** Compact mobile speaker • **SP-50B** Mobile speaker • **PG-2N** Extra DC cable • **PG-3B** DC line noise filter • **MC-60A, MC-80, MC-85** Base station mics. • **MC-55** (8-pin) Mobile mic. with gooseneck and time-out timer • **MA-4000** Dual band antenna with duplexer (mount not supplied) • **MB-201** Extra mobile mount

Specifications and prices subject to change without notice or obligation
Complete service manuals are available for all Kenwood transceivers and most accessories.

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